INJURIES
OF THE HAND

INJURIES OF THE HAND

by

RONALD FURLONG, F.R.C.S.
Assistant Orthopædic Surgeon, St Thomas's Hospital;
Orthopædic Surgeon, Rowley Bristow Hospital, Pyrford
and Queen Victoria Hospital, East Grinstead;
Honorary Consulting Orthopædic Surgeon to the Army
and the Royal Hospital, Chelsea

With 99 Illustrations



LONDON
J. & A. CHURCHILL, LTD.
104 GLOUCESTER PLACE, W.1.
1957

PREFACE

SURGERY of the hand will doubtless become increasingly important as time goes on. The standard of result obtained, to be acceptable to-day, must be considerably higher than it was a generation ago. Improvement has often come from simplified conceptions but more complex techniques, and it is the duty of the specialist to present to both surgeon and student alike a simplified abstract of the accepted views and methods of to-day.

This book describes the current teaching and practice of the Orthopædic Department of St. Thomas's Hospital. Throughout the volume reasonable simplification, without over-simplification, has been the aim of the Author, thereby bringing it into line with the traditional teaching of the Department in the sphere of general orthopædic and fracture treatment.

The purpose of the book is to help the recently initiated surgeon who already knows the principles of surgery, but who has not had much experience in hand surgery. It is a kind of instruction manual to be referred to when need arises. It is essentially practical in outlook and ambitious campaigns of reconstruction are not included. The standard volumes on plastic and hand reconstructive surgery are more fitting repositories of such skill and knowledge; patients with such injuries should be dealt with in surgical centres devoted to such work.

It is hoped also that some students in their busy final year will find time to read at least some of the chapters.

The assemblage of a representative collection of illustrations is not easy, but the ready co-operation of the Photographic Departments of St. Thomas's Hospital and the Rowley Bristow Hospital are responsible for the excellent quality of the pictures. To my advisors, helpers, and Secretary, I offer my thanks.

RONALD FURLONG.

CONTENTS

INTRODUCTION

On the Use and Importance of the Hand

THE usefulness and importance of the hand cannot be gainsaid. Anatomists and others are apt to draw attention to the wonderful differentiation and intricacy of mechanism found in the hand. The truth is that from the reptilia upwards there has been relatively little modification in anatomy. The manus of the horse, or deer, or even of the light brachiators, has undergone considerable specialized modification from the ideal manus of the reptilia. In the case of man the specialization has taken place in the brain. Enhanced muscular control and improved tactile sensibility have converted, with little alteration, the hand of the lower primate into the hand of a musician.

The usefulness of the hand depends on its control, not on its form or shape. Patients with moderate congenital deformities of the hand, such as syndactyly or suppression of two metacarpal rays, find no inconvenience with regard to power and dexterity. Acquired mutilations, especially if accompanied by joint stiffness, are a different matter. The pattern of function and control is greatly upset and the patient with an acquired loss of hand substance is at a great disadvantage compared with the patient having a congenital deformity of similar appearance and degree.

The importance of the hand as an instrument of work is now well recognized. Efforts are now made to spare working hands from injury and to treat injured hands more effectively.

CHAPTER 1

RELEVANT SURGICAL ANATOMY

The Flexor Profundus Digitorum

Individual and separate movement of a profundus tendon is hardly possible, even in those persons especially trained in digital dexterity. It should be considered that the flexor profundus muscle is a single muscle ending in four tendons. It is capable only of a mass action rather than individual activity of a separate tendon. Phylogenetically the flexor longus pollicis is a portion of the flexor profundus digitorum which by man's adaptability has become separated from the rest of the muscle bulk, thereby permitting individual and separate action.

The profundus tendons arise from muscle in the lower quarter of the forearm, and, passing deep to those of the sublimis, pursue their course across the palm to enter the digital sheaths. Each tendon is embraced by the corresponding sublimis tendon in the sheath and courses over the phalanges to be inserted into the distal phalanx. The excursion of the profundus tendons at the wrist is about 4 inches.

The tendons are enveloped with paratendon at their origin. The typical mesotendon arrangement is established as the tendons pass over the wrist to enter the palm. This mesotendon conveys blood to the tendon while permitting the necessary amplitude of excursion. The origin of the lumbrical muscle from the profundus tendon interrupts the mesotendon attachment. Distal to the lumbrical origin the tendon is invested by loose paratendon as far as the synovial reflexion of the digital sheath. The lumbrical muscles of the index and middle fingers arise from the radial aspect of the appropriate tendon. The lumbricals of the other two fingers arise from adjacent aspects of two tendons. These muscle origins from the profundus tendons have an important significance in preventing proximal spread of infection from a thecal whitlow.

Distal to the lumbrical origin there is about 4 inches of profundus tendon without mesotendon cover and, therefore, with an impoverished blood supply. This is, in part, made good by the vinculum longum attachment, whereby blood vessels are enabled to enter the tendon at the level of the proximal interphalangeal joint. The vinculum longum has sufficient length to accommodate the normal excursion of the profundus tendon at this level. The presence of a vinculum is of exceptional importance, because without it, or at least its blood supply, the tendon may undergo central necrosis giving rise to the clinical syndrome of snapping finger.

The function of the profundus tendons is well known. They are the power behind grasping. The power of grasp supplemented by the

sublimis and intrinsics is immense. The profundus tendons do not make an important contribution to fine movements of the hand. They grasp in unison and stabilize individual fingers, but the motive power of manual dexterity is supplied by the sublimis tendons and the intrinsic muscles.

The flexor longus pollicis muscle is on the same plane as the flexor profundus digitorium but is almost completely separated from it in its action. With the thumb extended, the muscle belly reaches to within an inch of the radial styloid. Thereafter the tendon is invested in mesotendon which permits individual action. The mesotendon splits to encase the flexor profundus of the index and those to the rest of the fingers. The mesotendon arrangement envelops the tendon distally to the region of the metacarpo-phalangeal joint. Thereafter, until its insertion, the tendon lies free in a digital synovial sheath. The fibrous sheath is represented by a pulley at the level of the metacarpo-phalangeal joint; distally the sheath is considerably thinner.

The Flexor Sublimis Digitorum

The sublimis tendons have greater individuality than the profundus. The sublimis muscle belly in its proximal part is one entity formed from the union of four muscle bands from which the tendons arise. Without special training it is possible to activate individual sublimis tendons freely. For practical purposes it may be considered that the flexor sublimis digitorum consists of four distinct muscle bellies, able to be used separately or in unison. The tendons arise in the lower third of the forearm and, passing deep to the anterior carpal ligament, cross the palm of the hand. They enter the fibrous digital sheath, and over the proximal phalanx the tendon divides into two slips which pass round either side of the profundus tendon to join again deep to it. The united sublimis tendon is flattened and, passing on, is inserted widely into the palmar surface of the middle phalanx. Throughout their course in the lower third of the forearm and across the palm, the sublimis tendons are surrounded by a reflexion of synovial tissue in the form of a mesotendon, similar in conception to the mesentery. The tendons are loosely attached by this means to the volar aspect of the lower part of the forearm and carpus. The mesotendon conveys blood vessels which spread over the surface of the tendon in the subserous layer supplying blood to its structure. The areolar tissue of the mesotendon is sufficiently slack to permit the normal excursion of the tendon, which in the lower third of the forearm is about 2 inches. The mesotendon stops where the tendon enters the digital sheath. Between this point and the insertion, which is about 2 inches, the tendon is bereft of all blood supply. The vinculum breve is not a vestigial remnant of the mesotendon arrangement and is, in fact, only the synovial reflexion at the tendon insertion. It is not of practical importance.

Usually the loss of flexor sublimis action causes no disability. There is, of course, some weakness in the gripping force of the involved finger but as a rule all fingers grip in unison so this is unnoticed. The tendon

does, however, have a specific action related to its perforation by the profundus. By being superficial to the profundus over the proximal phalanx it has a better purchase on, and a better angle of approach to its insertion. Thus the sublimis by itself initiates proximal interphalangeal joint flexion and later shares this with the profundus. After loss of a single sublimis tendon the function will pass for normal, but the professional pianist may claim to lack some strength. The only individual movement which is lost is flexion of the proximal inter-phalangeal joint with the rest of the fingers held rigidly extended. In this position the profundus tendon is out of action, as is demonstrated by the uncontrolled distal joint. Such a posture is not obtainable after loss of sublimis tendon but this probably is of no practical importance.

The Lumbrical Muscles

These are four in number and they arise from the radial aspect of the profundus tendon of the corresponding finger. The lumbricals of the index and long fingers arise solely from one profundus tendon. For the ring and the little fingers the lumbricals arise also from the ulnar aspect of the adjacent tendons. Differential motion between the profundus tendons is not great and the lumbricals at their origins are bipennate, to accommodate slight individual differences in movement. In all instances, the distal end of the lumbrical muscle, having passed to the palmar aspect of the transverse metacarpal ligament, joins with part of the interosseous tendon to be inserted into the lateral band of the extensor cap just distal to the metacarpo-phalangeal joint. The tendon fibres are not always easy to trace and sometimes they seem to fuse with the interosseous tendons immediately distal to the transverse metacarpal ligament.

The excursion of the proximal end of the lumbrical muscle is, of course, the same as the excursion of the profundus tendon. It is, in fact, greater than 2 inches. With the fingers fully clenched the lumbrical origin is at the level of the transverse carpal ligament, whereas with the fingers fully extended that origin has travelled distally nearly to the level of the transverse palmar crease. The muscle is at its shortest with the fingers fully extended and at its longest with the fingers fully clenched. The muscle fibre length of about a $\frac{1}{2}$ cm. caters for excursion and by inference the power of an individual lumbrical muscle cannot be very great. All the same, the fact that the muscle has a mobile origin means that its resting length can be increased and hence its power of contraction augmented.

These puzzling muscles provoke speculation as to their purpose and function. Without guessing it can be shown experimentally and clinically that the lumbrical muscles have the ability weakly to extend the interphalangeal joints. Equally, they are able to begin flexion at the metacarpo-phalangeal joints because their angle of approach is superficial to the transverse metacarpal ligament. This action must be weak as the resting length is short. Probably the most practical function of the lumbrical muscle occurs when the fingers are clenched. In this position

the muscle is at its longest and its total power will be the sum of passive stretch and active contraction. In this way its greatest power is available to augment flexion of the metacarpo-phalangeal joints as the fingers are clenched.

The Interosseous Muscles

The general arrangement of the interosseous muscles is well known to every student. The detailed anatomy is complicated and of practical importance. In the lower mammals there are, as a rule, seven palmar interosseii which form a separate layer amongst the complicated intrinsic muscle system. In primates the number is less and in man even further reduced to three. The absent muscles have not been completely suppressed but have migrated dorsally to become fused with the dorsal interosseii.

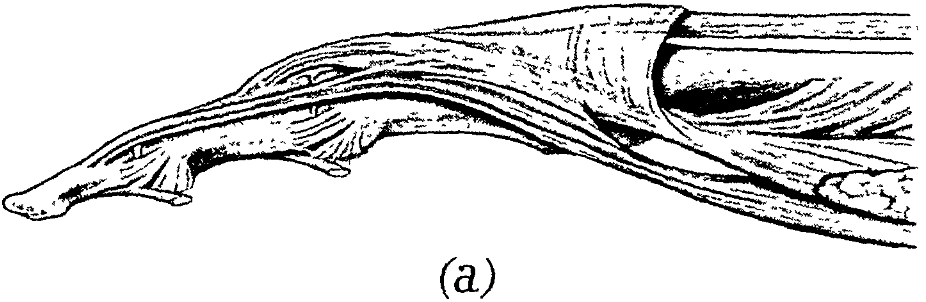
The Palmar Interosseii. The three volar interosseous muscles, which are known for their power to adduct towards the long finger, lie in the second, third and fourth metacarpal interspaces. They have a discrete origin from the proximal and volar aspect of the second, fourth and fifth metacarpals. The muscles are long-fibred and fusiform in shape. They become tendinous at the metacarpal necks and pass distally dorsal to the transverse metacarpal ligament and in direct relationship to it. The tendons are inserted into the extensor aponeurosis of the index, ring and little fingers, with a subsidiary insertion into the joint capsule. The third palmar interosseous has, often, a direct insertion into bone and this explains the frequent observation in ulnar nerve paralysis that the little finger tends to lie abducted from its neighbour when at rest.

The angle of approach of the palmar interosseii to their insertions is well in front of the axis of the knuckle joint. Their action, clearly, is to flex the metacarpo-phalangeal joints when the extensor communis is relaxed and to extend the terminal phalanges during the first half right angle of knuckle flexion. Their secondary action, with the knuckle joints stabilized straight by the extensor communis, is to adduct the fingers towards the long finger.

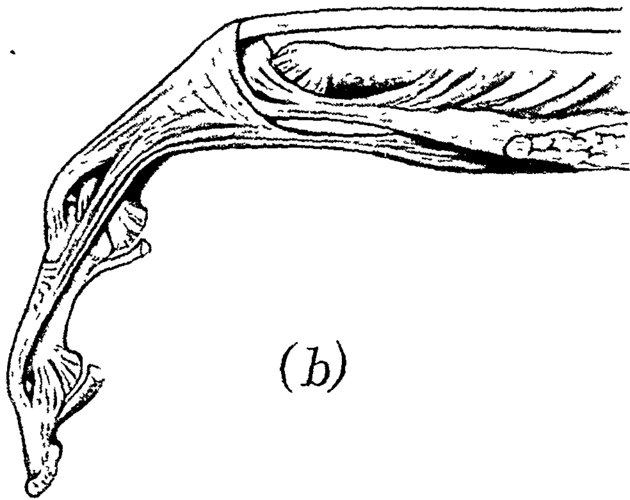
The Dorsal Interosseii. These are composite muscles containing vestiges of their palmar companions which have long since departed. They are four in number and they lie in the first, second, third and fourth interosseous clefts. Arising from adjacent surfaces of the metacarpal shafts the muscles are bipennate in form and of short fibre length. This indicates good strength but poor excursion. The tendon forms at the level of metacarpal neck and passes onwards dorsal to the transverse metacarpal ligament on a level with the axis of the joint. The dorsal interosseous muscles are inserted into the lateral aspects of the phalangeal base. The angle of approach which the tendon makes with the bone is not favourable for initiating metacarpo-phalangeal flexion.

The tendon of the volar component passes on the palmar aspect of the dorsal and is inserted into the extensor aponeurosis. In the case

of the index finger both components are inserted into the base of the proximal phalanx. This arrangement adds to the power of abduction of the index finger with the knuckle extended and so enhances all kinds of pinching and grasping action. The insertions of the other three dorsal interosseii are divided between bone and dorsal expansion so that they are



(a)



(b)

FIG. 1

(a) The extensor tendon is holding the metacarpo-phalangeal joint straight and is assisting the intrinsic muscles to extend the two distal joints.
(b) The intrinsic muscles are flexing the metacarpo-phalangeal joint and receiving the assistance of the extensor tendon in straightening the distal joints.

able more effectively to extend the interphalangeal joints than the first dorsal interosseous. In varying degree the interosseous muscles are able to flex the metacarpo-phalangeal joints, extend the interphalangeal joints and deviate the axis of the fingers with the knuckles extended (Fig. 1).

Flexion of the metacarpo-phalangeal joints can be initiated by the palmar interosseii or the palmar component of the dorsal interosseii

together with the lumbricals. Flexion of these joints is continued by the above muscles together with the dorsal interosseii which come into play with increasing mechanical purchase as flexion continues. In so far as these muscles are inserted into the extensor aponeurosis, the interphalangeal joints will be extended at the same time. If the forearm flexors are used to overcome the extension effect of the intrinsic muscles these latter will have even greater power to flex the metacarpo-phalangeal joints because they will be elongated and hence more powerful. The total muscle tension will be the sum of increased passive stretch and active contraction.

Axial deviation is only possible when the metacarpo-phalangeal joints are held straight by the common extensor. In this position the dorsal muscles are able to spread the fingers. That the extensor communis muscle does not of itself diverge the fingers is shown as follows: starting with the fingers fully extended and diverged, if the index or middle fingers are bent at the proximal interphalangeal joint by individual action of the sublimis tendon the proximal phalanx instantly deviates in an ulna direction. Flexion of the interphalangeal joint slackens off the volar component of the dorsal interosseous muscle, thereby permitting the finger to assume a position of ulnar deviation which is the result of combined flexor and extensor action. Adduction of the extended fingers is the result of palmar interosseous action.

The Digital Tendon Sheath

Nomenclature is variable but it should be precise. The term digital sheath refers to a fibrous tube of mechanical significance on the volar surface of the digits. The digital sheath is the fibrous tunnel through which the tendons pass during their course along the palmar aspect of the phalanges. The tendons have to be held back against the phalanges, otherwise on pinching action they would tend to follow a straight course; in fact a chord of an arc. The sheath extends from the distal interphalangeal joint proximally to the level of the transverse palmar creases. It is thickened over the proximal phalanx and this is called the proximal pulley. This is, in fact, merely thickening of the fibrous sheath which extends the whole length of the finger. It is thinned and sometimes deficient over the proximal interphalangeal joint. Lining this fibrous sheath is the parietal layer of synovial membrane. The proximal end has an unmistakably obvious border. Mostly the fibres are disposed transversely but over the proximal interphalangeal joint they are disposed obliquely to prevent kinking on joint flexion. The thumb also has a thin fibrous sheath which extends from the distal phalanx over the whole of the proximal phalanx as far as the sesamoid bones where it is much thickened. Proximal to this there is no need of a sheath where the flexor longus pollicis passes deep to the thenar muscles. In this position the tendon does not stand away from the bone and it is invested with paratendon in mesentary-like form.

The Synovial Sheaths

The flexor tendons of the fingers and thumb, from their origin at the musculo-tendinous junction, are surrounded by loose areolar tissue so disposed as to permit motion and at the same time to ensure a blood supply to the tendons.

The analogy of the peritoneal cavity, with the intestine invaginated from behind and held restrained by the mesentery, is obvious. The synovial membrane is arranged in two layers, tendinous and parietal, with a mesotendon attaching each tendon to the parietes. It is as though the

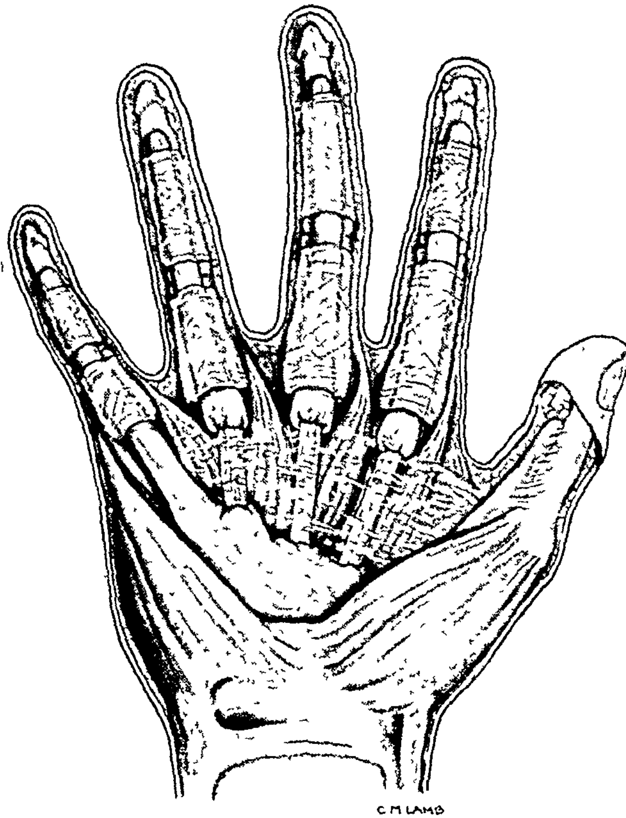


FIG. 2. The preputial arrangement of the digital synovial sheath is demonstrated. At the lumbrical origin the tendons are invested with paratendon. The ulnar bursa lies proximal to this.

tendons have been invaginated from the ulnar aspect of the limb. The potential space between the two layers permits free gliding and the looseness of the mesotendon permits required excursion.

The tendons are arranged in two groups: the sublimis, superficial, and the profundus, deep. Sometimes the flexor longus pollicis has a separate invagination and mesotendon and sometimes it is part of the deep arrangement.

The four sublimis tendons are invaginated together and have a common mesotendon. The arrangement favours a mass action of each group but

the sublimis tendons are separated from each other sufficiently to permit individual movement. This is of limited extent, as can be demonstrated easily. If the fingers are held straight, active flexion of an individual finger as far as possible causes pain in the lower part of the forearm. This, presumably, denotes tension within the mesotendon which is referred to the musculo-tendinous junction.

The deep flexors are similarly disposed; spread out within two layers of the deeper mesotendon. It is less differentiated than the superficial and permits of little more than a profundus mass action, but the muscle is hardly capable of more than this.

The synovial space, common to all the tendons of the four fingers, is known as the ulnar bursa. In the case of the index, long and ring fingers, the mesotendon and potential space extend distally to the lumbrical origin. The little finger has a different arrangement and the synovial space continues distally throughout the length of the tendons in the finger. No satisfactory explanation for this special arrangement has been given. The surface marking of the proximal limit of the lumbrical origin in extension is 1 inch proximal to the distal palmar creases (Fig. 2).

Distal to the lumbrical muscle origins another arrangement is in force. The tendons now enter the fibrous digital sheath. The mesotendon is absent and remains only as a vestige in the vinculum longum to the profundus tendon. A mesotendon in the fingers would be an embarrassment to smooth function. Both tendons in each finger are surrounded by a continuous layer of endothelial cells. The tendinous layer is continued to the insertion of the profundus, whence it is reflected back along the inner aspect of the fibrous digital sheath. In the case of the sublimis tendon the proximal synovial arrangement is similar. At the distal end the tendinous synovial layer merges with the parietal layer at the level of the middle phalanx. At the palmar end of the fibrous sheath the synovial membrane is prolonged proximally until it meets the forward edge of the lumbrical origin. At this point it is reflected and once more it becomes continuous with the tendinous layer. This layer at this point is loosely attached to the tendon. The preputial-like redundance of the endothelial tissue permits normal tendon excursion.

The flexor longus pollicis tendon may be separate in its gliding arrangements from the others. In the lower part of the forearm, and as far distally as the metacarpo-phalangeal joint, the tendon is invested with mesotendon and in a manner similar to the other tendons. The potential space surrounding this tendon is known clinically as the radial bursa. At the metacarpo-phalangeal joint the mesotendon stops and the normal digital sheath arrangement, similar to the fingers, supervenes. There is continuity of synovial space between the digital and mesotendon sections of the flexor pollicis longus.

The anatomical arrangement has a practical bearing on the spread of infection. An infection introduced into the digital sheaths of either the thumb or little finger has the capacity to spread from the tip of the finger

to the musculo-tendinous junction. Infection introduced into the digital sheath of the index, long or ring fingers may spread proximally only to the level of the transverse palmar crease, where the reflexion of the synovial sheath limits further progress. This is true only of acute infections however, for chronic tuberculous tenosynovitis may spread beyond the confines of the synovial sheath and advance along the indicis tendons toward the wrist, forming a sausage-like swelling. Presumably the subsynovial tuberculous infection spreads beneath the visceral layer of endothelium regardless of the anatomy of the parietal layer.

The Extensor Tendons

Each of the four fingers is served by the extensor communis digitorum. Both the index and the little fingers have, in addition, individual extensor tendons, each with a separate muscle. The tendons of the extensor

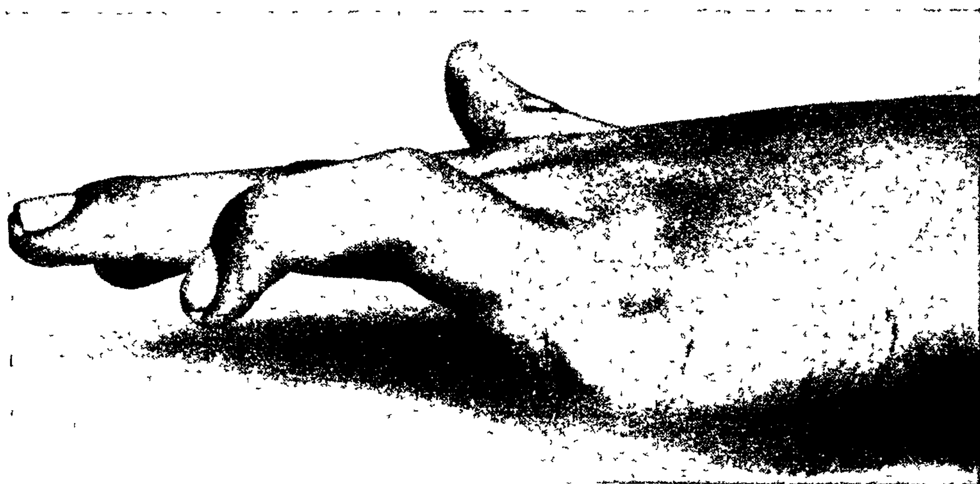


FIG 3. The attitude of the annularis is the result of unopposed extensor tendon action. The intrinsics have been divided.

proprius indicis and extensor quinti digiti lie to the ulnar side of the appropriate communis digitorum tendon. Individual action of the extensor proprius indicis is noted in the conventionalized sign indicating the 'Way out' and that of the extensor quinti digiti in the extended little finger of the genteel barmaid pouring bottled beer. The specialized extensor tendons run a course parallel with the communis slips to the index and minimus, and at the extensor expansion over the metacarpo-phalangeal joint the tendons coalesce.

The fibres of the extensor tendons pass onwards through the expansion to course centrally over the proximal phalanx and interphalangeal joint gaining bony insertion at the base of the second phalanx. The extensor tendons passing over the hump of the knuckles have to be held there by a special arrangement of the aponeurosis. Transverse fibres pass from the central tendon round the metacarpal head and are attached anteriorly to the joint capsule. These fibres prevent dislocation of the tendon and

permit the extensor expansion to slip over the knuckle joint in a radial manner. The interosseous tendons are inserted obliquely into this aponeurosis in front of the axis of the joint, so that their action is flexion. Fibres passing obliquely forwards contain elements of the long extensors, interosseii and lumbricals, to form lateral bands running close to the central tendon. After passing forward on either side of the proximal interphalangeal joints, the lateral bands fuse again, after convergence over the middle phalanx, and then pass onwards to be inserted into the base of the distal phalanx.

The reasons for this complicated insertion are not easy to understand but it will be seen that the metacarpo-phalangeal joint is extended only by the communis digitorum and the proprius indicis and quinti digiti muscles (Fig. 3). The two interphalangeal joints are extended by the combined action of the long extensors and the intrinsic muscles of the hand. With the metacarpo-phalangeal joints held straight by the long extensors, which is their primary action, the interphalangeal joints are straightened by the intrinsic musculature. This fact is illustrated clinically by the claw hand deformity accompanying ulnar nerve division.

With the knuckle joints flexed, the short fibred (25 mm.) dorsal interosseii are working in their inner range and are consequently less powerful. In this position interphalangeal extension is carried out by the long extensors. The proximal interphalangeal is powerfully extended through the continuity of the central slip. The distal joint is less strongly straightened through the medium of the extensor aponeurosis and lateral bands. In brief, the interosseii are dominant in extending the distal joints with the metacarpo-phalangeal joints held straight. With the knuckles bent intrinsic power to extend the interphalangeal joints is weakened but this loss is neutralized because the long extensors are working to greater advantage in this posture.

The function of the extensor tendons is so closely knit with that of the interosseii that all finger movements depend for their control on co-ordinated and synergic action.

The Skeleton of the Hand

An anatomist's knowledge of the skeletal anatomy is happily unnecessary for a surgeon. The recognition of a carpal bone by palpation in the pocket advertises a high level of tactile sense but little else.

The Carpal Joints. The wrist joint is of importance because of its liability to injury. Though a mobile link between the hand and arm, it depends a great deal for its usefulness on stability. A wrist fixed in the position of function is no great disability. Considering the complexity of wrist movement, this is surprising.

The wrist joint is capable of circumduction and comprises the radio-carpal and the intercarpal joints. Dorsiflexion of the hand takes place mainly at the radiocarpal joint, whereas the intercarpal joint is mostly concerned with palmar flexion. This fact can be observed clinically.

With the wrist viewed from the side, and starting in the fully dorsiflexed position, it will be seen that the point of acute angulation between the back of the hand and the forearm is just proximal to the radial styloid. As the wrist is palmar flexed it will be seen that the centre of motion moves distally. In the position of full palmar flexion the point of acute angula-



FIG. 4 (*a*). Dorsiflexion is a function of the wrist joint whereas palmar flexion takes place at the intercarpal joint.

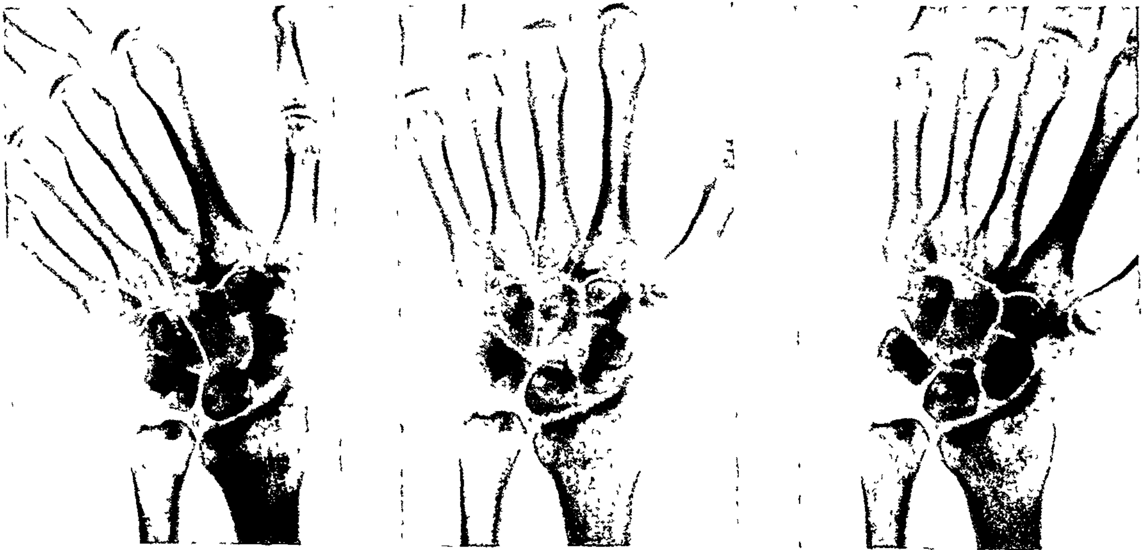


FIG. 4 (*b*). In ulnar deviation from the neutral position most of the movement occurs at the intercarpal joint. In radial deviation, however, the carpus swings on the radius.

tion is distal to the radial styloid, at the intercarpal joint (Fig. 4a). Similarly radial deviation is a movement taking place at the radiocarpal joint, with a small contribution from the intercarpal joint. Of more practical importance is the fact that ulnar deviation occurs almost totally at the intercarpal joint (Fig. 4b). The scaphoid is a component of both rows of carpal bones and when the wrist moves into abduction the axis

of the bone alters to permit the distal row to move laterally. The tuberosity of the scaphoid becomes prominent on the volar aspect of the wrist as it tilts to accommodate the sideways movement of the carpal bones. This is an important feature in the mechanism of fracture of the scaphoid. Dorsiflexion is not the essential cause. Forced radial deviation, in fact, fractures the bone.

The Carpal Bones. Only two of the carpal bones are of interest : the semilunar and the scaphoid. The semilunar bone is outstanding because of its liability to dislocate forwards as the result of forced dorsiflexion of the radiocarpal joint. Occasionally this forward displacement is accompanied by a fracture of the scaphoid, in which the adjoining fragment of the scaphoid accompanies the semilunar forward. The more complex injury is the result of forced dorsiflexion and radial deviation.

The scaphoid is more liable to fracture than any other of the carpal bones. The proximal and distal rows of carpal bones are joined at their radial extremities by the scaphoid which is, in fact, a component of both rows and joins them like the apex of a wish-bone. During forced radial deviation the scaphoid sustains a sheering strain across its waist and if the force is not fully absorbed by rotation, the bone is liable to break.

The Carpo-metacarpal Joint of the Thumb. This is an example of a saddle joint. The component joint surfaces are complete. In the main the movement permitted is similar to that of a condyloid joint, with the addition of a greater degree of rotation. The joint at the base of the thumb is a stable joint, not liable to dislocation, and is freely mobile.

The Metacarpo-phalangeal Joint of the Thumb. This differs from the other metacarpo-phalangeal joints in that, in some ways, it resembles more a hinge than the condyloid joint. In extension it is stable and lateral movement is not permitted, but this is due more to muscle control than to ligaments. In slight flexion certain lateral mobility is possible. This is an uncommon feature with hinge joints. It differs from the other metacarpo-phalangeal joints in that the amount of flexion permitted is limited. The amount available is variable in different individuals and is often restricted to 40 degrees, whereas 90 degrees of flexion is a rarity.

The other Metacarpo-phalangeal Joints. These are condyloid joints. That is to say they permit flexion and extension, together with a small amount of axial deviation and rotation. Deviation is possible with the fingers extended, because in this position the collateral ligaments are slack. A certain degree of rotatory movement is possible with the fingers bent, so that they can, for instance, adapt themselves to grasping a tennis ball. The dorsal interosseii and long extensor muscles control abduction movement of these joints and the palmar interosseii control adduction. As the joints are flexed the collateral ligaments tighten, so that deviation becomes progressively more restricted. These collateral ligaments are firm, round bands which run obliquely forward and distally from the metacarpal heads. The anterior capsule is very firm and is the major structure preventing forced dorsiflexion at these joints. It is closely associated

with the deep transverse ligament of the palm. The capsular attachment to the base of the phalanx is conventional but its metacarpal attachment is further proximal than would be supposed. The capsule blends with the periosteum of the volar aspect of the bone. It lies in contact with the cartilage covered condyle of the metacarpal head (see Fig. 96).

The Inter-phalangeal Joints. The proximal interphalangeal joints are hinge joints, which means that they are stable in extension and equally stable in all degrees of flexion. The arrangement of the ligaments is similar to that of the metacarpo-phalangeal joints. The collateral ligaments are thickened and form bands but they do not become more tight as flexion increases because there is no anterior hump of condyle which has the effect of tightening the lateral ligaments during flexion. The flexor tendons ride freely over the anterior capsule of the proximal interphalangeal joint but the profundus tendon is fairly firmly incorporated with the anterior capsule of the distal interphalangeal joint. This has to be borne in mind when removing a stump of the profundus tendon from the tip of the finger. Care must be taken that the interphalangeal joint is not opened or damaged, otherwise intractable stiffening in the flexed position will almost certainly result.

The Nerves of the Hand

The Median Nerve. The median nerve passes into the hand deep to the anterior carpal ligament and superficial to the flexor tendons. It lies deep to the palmaris longus tendon. If this is absent, the nerve will be found lying immediately to the ulnar side of the flexor carpi radialis. The nerve is distinguished from the tendons because it has a different colour; it is wider and striated. During the course of surgery the nerve is not likely to be accidentally divided, unless it is completely embedded in scar tissue or lying outside its normal course.

The nerve passes distally in the palm, inclining a little to the radial side, and at a point level with the fully extended thumb it divides into its terminal branches. Whenever there is reason to operate or explore this part of the palm, the first thing to be identified is the motor branch of the nerve. It may be difficult to find. Division is a disaster which will be only too obvious to the patient.

The main trunk ends in a slight enlargement, from which sprout the five sensory branches (Fig. 5). It is unfortunate that the median nerve often gets damaged at its point of termination. It lies immediately beneath the concave proximal part of the palm and in this situation is liable to be involved by penetrating wounds. Repair is difficult. The motor branch, passing directly transversely into the thenar muscles, has a visible course of $\frac{1}{2}$ or $\frac{3}{4}$ of an inch and then is lost to view. If it is damaged by a penetration as it lies amongst the thenar muscles, there will be no hope of a successful repair.

The sensory branch which passes to the radial aspect of the thumb lies over the thenar muscles. It is very obvious. That supplying the ulnar

side of the thumb lies in a similar position, directed towards the first cleft. The branch passing to the radial side of the index finger lies parallel to the flexor tendons of that finger. It passes into the index finger, rather more on the palmar aspect of the digit than is the case with the others. The nerves passing forward to supply the cleft between the index and the long finger and the long finger and the annularis, lie between the appropriate tendons and at a similar depth in the palm. The digital nerves are accompanied by digital arteries, branches of the superficial palmar arch. At the level of the transverse palmar creases these nerves divide into their two



FIG. 5. Division of one or more of the terminal branches of the median nerve could be difficult to repair.

terminal branches to supply adjacent sides of the cleft. They then incline deeply beneath the superficial transverse metacarpal ligament and enter the digit at its mid-lateral aspect. From thence the nerves pass along the finger, finally to disappear ramifying in the pulp of the tip.

The Ulnar Nerve. The ulnar nerve enters the hand by passing closely to the radial side of the pisiform bone. At this point it has already divided into its two terminal branches. The superficial or sensory branch passes directly forwards, dividing into its two terminations. The radial one of the two supplies the cleft between the small and the ring finger. The other terminal nerve supplies the ulnar side of the little finger. They pass superficially over the hypothenar mass beneath the deep fascia

and enter the finger in a way similar to that adopted by the other digital nerves.

The deep branch of the ulnar nerve burrows between the two heads of the opponens minimi digiti and passes into the hypothenar mass. Having supplied the muscles of the hypothenar eminence, the nerve passes across the floor of the palm to the adductor muscles of the thumb. The medial lumbricals and all the interosseous muscles are innervated by the deep branch of the ulnar nerve (Fig. 6).

The deep head of the flexor brevis pollicis is frequently innervated by the ulnar nerve. The nerve supply is derived from the termination of the

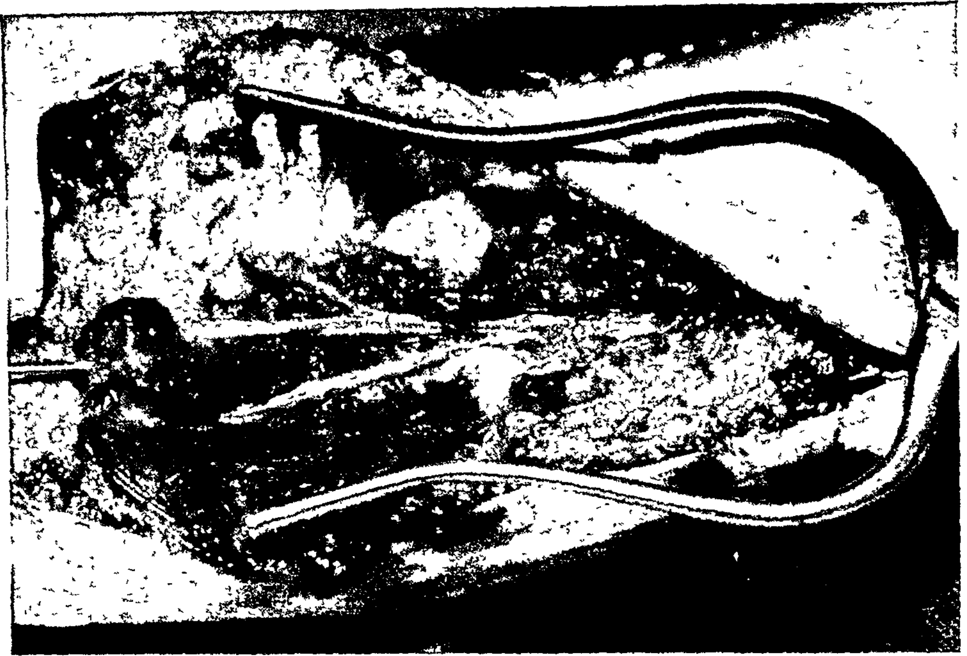


FIG. 6. The motor termination of the ulnar nerve diverges at the pisiform bone. Hence it passes between the two heads of the opponens brevis minimi digiti (one head of which is retracted), and passes across the palm in the direction of the head of the second metacarpal.

deep branch. Sometimes the flexor brevis has a double supply, being served by both median and ulnar nerves.

The Radial Nerve. In practice the terminations of the radial nerve are ignored by the surgeon who deals with injuries to the hand. Both the median and ulnar nerves supply the dorsal aspects of the middle as well as the terminal phalanges. The overlap is such that the loss of cutaneous sensibility, following division of the posterior interosseous nerve or the cutaneous nerve of the forearm, is slight. However, during the operation for a tendon transfer, following a rupture of the extensor longus pollicis, the terminal twigs of the radial nerve are visible and it is as well to avoid wilful division of these fibrils, otherwise the patient may ter of areas of cutaneous anæsthesia around the base of the t' fingers.

One per cent. Xylocaine is a very effective local anæsthetic. It seems to be more diffusible than Procaine so that hyalase is not necessary. When the needle has penetrated the cervical fascia 10 c.c. of Xylocaine should be injected. Tingling may be felt in the hand and this confirms that the tip of the needle is in the correct location. Anæsthesia is slow to develop, sometimes taking twenty minutes to reach the maximum. If this is not good enough, a further injection may be necessary. In this case the needle is directed a little upwards so that the higher part of the brachial plexus is infiltrated. A Horner's syndrome may or may not accompany a successful brachial plexus block.

The Technique of Digital Block. Two weals are raised, one on either side of the affected finger at the level of the web. A subcutaneous infiltration is carried out around the base of the finger. The needle is then directed deeply towards the digital nerve at the base of the phalanx on either side. Xylocaine, 2%, is used and 2 or 3 c.c. are enough. Sufficient time must be allowed for the anæsthesia to be complete. Adrenaline must not be added to the Xylocaine solution for fear of causing ischæmia of the finger.

On the Choice of Instruments

A general surgical setting may be adequate for general surgery or an autopsy but these instruments are not fine or delicate enough for surgery of the hand. Tissue must not be damaged by the surgeon.

Our surgical forbears lived in an era of antiseptic surgery and believed in it; in this generation we have been taught to believe in aseptic surgery. Progressives have raised the voice of doubt and unwittingly the truth has been furnished by plastic surgeons. Modern surgery has an atraumatic conception. Absence of septic inflammation after surgery is explained not by absence of organisms in the wound but by avoidance of hæmatoma and especially avoidance of tissue damage during the course of the operation. Dissecting forceps should be delicate and skin hooks should be used to elevate the skin. Heavy 8-inch dissecting forceps find no place in the setting. Fine artery forceps are necessary so that only the vessel need be taken. The constant pressure of a small, self-retaining retractor is less damaging to the tissue than a retractor held by a powerful assistant. Tissue damage is avoided by assuring that fine instruments are delicately used. Hæmatoma is prevented by hæmostasis and drainage.

The only special instruments peculiar to tendon surgery are the following: Tendon strippers are necessary so that a doomed tendon can be removed and discarded without exposing the whole of its course by a skin incision. A tendon stripper is a tube of metal a ¼ inch long, the diameter of a flexor tendon, the leading edge of which is sharpened. It has a handle. It is threaded over a tendon and driven along its course, dividing adherence to the surrounding tissue. When the end is reached the stripper severs the terminal insertion and the tendon is easily removed. Three strippers of different diameters are necessary to accommodate

varying sizes of flexor tendons. A malleable probe about 8 inches long is necessary. It is widened at its middle so that it will force a passage through stenosed tissue for the tendon graft trailing behind it. The probe ends as an inverted cone into which the graft is fixed by a stitch. This device enables the surgeon to ease a tendon graft in position without the irritations normally associated with use of the usual form of probe. Needles must be fine and with cutting edges. No. 6 curved are very useful and they may be either eyed or eyeless. A No. 13 or a No. 16 curved cutting needle for suture of the skin is a necessity. In addition it will be necessary to have some 3-inch triangular pointed, straight needles. These are used either for suture or for transfixion purposes. Finally, surgery of the hand is made more comfortable and easy if a silhouette of a hand made of lead is available. By this means the part can be held still and available without wasting the ability of an assistant.

On Method of Skin Preparation

Preparation of the skin of the hand for elective surgery is different from the preparation of a hand which has just arrived in the Casualty Department, cut during the course of industrial work.

Deliberate Surgery. Preparation of the skin of the hand for deliberate surgery may be carried out in the following way: a few hours before surgery the hand is washed with soap and water. (In Chicago it is washed for ten minutes.) When it has been dried with a sterile or freshly laundered towel it is swabbed over with 70% alcohol, which is allowed to evaporate. Surgery confined entirely to the hand needs a skin preparation to the elbow. Surgery which will encroach on the forearm requires skin preparation above the elbow. It probably does not matter very much whether the arm is enclosed in a towel after preparation or not. A sterile towel can only protect the surface of the skin from contamination but this contamination can be instantly neutralized by a further wash with 70% alcohol. It may, however, be useful to use a sterile towel to cover the areas to be operated on. A towel keeps the orderly's hands and the Esmarch bandage from touching the area and a lot of needless and possibly virulent contamination is thus avoided. An Esmarch bandage must never be boiled immediately before use. Horrible burns have been produced on anæsthetized patients by winding a boiled rubber bandage round the arm. The interior of the bandage roll retains heat for a long time and the orderly's calloused hands are unable to appreciate that the warmth is sufficient to burn an unconscious patient.

For the final and immediate preparation in the theatre 70% alcohol is again used. It is not advisable to use a dyed solution for preparation because it may obscure the colour of the skin after surgery. Adequacy of vascularity after removal of the tourniquet is judged by skin colour, amongst other things. The recent appearance of Norbecutane has simplified skin preparation for elective surgery. It is a plastic preparation, soluble in amyl-acetate, which evaporates rapidly. When the skin

has been washed and swabbed with 70% alcohol in the ward, Norbecutane is painted or sprayed on to the area of operation. In the theatre, when all is prepared, the plastic skin is swabbed over with a detergent fluid. The smooth celluloid-like layer lends itself to decontamination by a simple detergent. The skin towel, a barrier to skin organisms, is already in position. It was put on in the ward. The method is attractively simple.

The lengthy ritual of skin preparation lasting for two days before surgery is now used only by traditionalists. Many surgeons do not prepare the skin at all. They merely cleanse the part with soap and water. In the theatre the skin is sterilized by 70% alcohol. The day of complicated ritualism in skin preparation is almost over. No surgeon who has watched a plastic colleague at work can be much impressed by the theories of aseptic surgery, but the precautions he takes to avoid a hæmatoma are impressive and therein lies the clue to healing *per primam.* Indeed we are now more interested in the soil than the seed.

Acute Surgery. A hand, cut by accident, requiring immediate surgery is almost certain to be surgically filthy, not to say socially dirty. The wound will be contaminated with organisms and therefore further contamination is not to be feared. The best all-purpose skin cleansing agent is a detergent solution which dissolves grease by lowering surface tension. It is difficult to wash, with soap and water, a hand badly mutilated with two or three fingers attached by skin alone. The first thing to do when the dressings are removed in the theatre is thoroughly to wash the affected region with volumes of some detergent preparation. It does not matter if the cleaning agent flows into the wound because it is already contaminated. When sufficient cleaning has been carried out, and it is quite a job, 70% alcohol is used to complete the preparation. The region to be operated upon is now enclosed in a sterile towel and an Esmarch bandage is applied. A blood pressure cuff is used as a tourniquet. The scene is now set for first-aid or initial surgery.

On the Use of the Tourniquet

A rubber tourniquet is no longer used to produce a bloodless field in the hand; it has been replaced by a blood pressure cuff inflated sufficiently to obliterate the pulse. An Esmarch bandage may be wrapped round the limb proximally, from the fingers, to exsanguinate before the tourniquet is applied. Alternatively the limb may be elevated for several minutes before the cuff is rapidly puffed up. A bloodless field is necessary for all reconstructive surgery of the hand, but it can be dangerous. These dangers must be anticipated and avoided so that the tourniquet is wholly advantageous.

If a tourniquet is left on for too long the limb may die. A tourniquet paralysis, however, can follow its application for a much shorter time. When the patient recovers consciousness it is found that one or more nerves are affected below the site of application. In a total tourniquet

paralysis of the arm all three nerves are involved and there will be complete paralysis below the elbow. Nearly always sensation remains. This seems to imply that the motor fibres of a peripheral nerve are more vulnerable to pressure than the sensory. Since sensation is unaffected in tourniquet paralysis, it is certain that motor recovery will take place. The lesion is neurapraxia but recovery is delayed sometimes for months. More often, however, the paralysis is transitory, lasting from a few hours to a few weeks and often only one nerve, for instance the musculo-spiral, is affected.

Paralysis is caused by the product of pressure and time; that is to say damage may be caused by much pressure for a short time or by mild pressure for a longer time. This is the reason why the Samways type of tourniquet is never used in the arm. The compression exerted by a blood pressure cuff, which is about 3 inches wide, is moderate, even and widespread. It does not matter whether the blood pressure apparatus is of the dial or manometer type. Whatever the blood pressure of the patient it will be found that between 260 and 300 mm. of mercury must be shown on the dial or gauge to exclude all blood during the course of the operation.

The question poses itself: how long may a blood pressure cuff be permitted to act as a tourniquet without danger of paralysis? One hour and a half is a usual time and on occasions an operation may drag on for two hours without any after-effects. It is right and proper, however, that the surgeon should feel uneasy after an hour and a half has passed since application of the tourniquet. In a well conducted theatre the time of application of the tourniquet is written in bold letters on a blackboard by an orderly. When an hour has passed this fact is announced to all and sundry. This will help the surgeon to keep a sense of proportion and not to be carried away by some surgical fantasy which may take two or three hours to perform. In planning some operation of elective surgery in the hand the surgeon must bear in mind the estimated time to be taken. It is much better to divide the surgical programme into two stages if there is the chance that one stage may exceed the reasonable exsanguination period.

From time to time a surgeon will find himself in difficulties which have presented themselves unexpectedly, so that the plan which he had started cannot be completed in an hour and a half. There is a simple method to cope with this difficulty. If it is realized during the course of the operation that it will take more than an hour and a half the tourniquet can be released for, say, five minutes in order that the anoxia of the tissues can be corrected. The wound is compressed with sterile gauze and pressure in the cuff is released. Blood flows in the arm; the fingers become pink and in spite of compression blood exudes from the wound, sometimes in considerable quantities. Five minutes is a long time but when sufficient time is judged to have passed, the arm with its sterile dressings, is elevated and the blood pressure cuff is rapidly puffed up again. The dressings are removed and the wound will be congested and swollen and the oozing will be impossible to stop. The operation is now so difficult that the surgeon

there and then vows never to be caught in similar circumstances again. However, the tissues of the hand and forearm, and particularly the nerves, have been saved in spite of the surgeon's added difficulties.

The disaster of forgetting to remove a tourniquet from the arm is extremely rare. In the case of the leg it happens not infrequently. It is fortunate that tourniquets applied eagerly by first-aid workers almost never work; otherwise they could do a great deal of harm. If a tourniquet has been left on for several hours the surgeon's behaviour will be dictated by circumstances other than surgical. After three or four hours the tourniquet paralysis will be permanent because of irreparable ischæmia of the nerves. After a longer time there will be dissolution of muscle leading to a Volkmann-like deformity and after longer still it will be obvious that there is gangrene of the limb below the elbow. A melancholy amputation will be carried out.

On Planning the Exposure

There are certain conventions which govern the place and direction of surgical incisions in the hand. The purpose of an incision is to expose; but careful planning may be necessary so that the rules of skin incision are not contravened. A hyperplastic or keloid scar is liable to develop after any incision which is made on the flexor aspect of the limb if it is subjected afterwards to longitudinal strain. The would-be suicide bears no stigma of the clumsy attempt to cut his throat unless he starts the incision at the mastoid process. The old-fashioned vertical incision along the anterior border of the sternomastoid for removal of the lateral lobe of the thyroid gland was liable to become extremely unsightly owing to hyperplastic scar formation. A boy of fourteen may be presented with an innocuous and symptomless semi-membranous bursa which his mother claims hurts him. If the bursa is removed through a vertical incision, the boy will afterwards have something to complain about. Keloid formation can be very troublesome. Longitudinal incisions along the flexor surface of the fingers, across the interphalangeal creases, or in the palm, frequently become keloid in appearance and have been named pernicious incisions. This sequence is not inevitable but it happens often enough to be anticipated and avoided.

Incisions parallel to natural creases are not subjected to longitudinal tension and many of them are quite invisible when healing is complete. The normal repertoire of surgery in the palm of the hand is catered for by standard incisions. If extemporization is necessary, it need only be borne in mind that an incision, wherever this may be, is innocuous if it follows closely the natural skin creases. Planning must be intelligent to serve both interests. It is possible to obtain an adequate exposure without paying the price in keloid or contracted scars.

Exposure of the Fingers. The whole length of a finger can be exposed on its palmar aspect by a lateral incision sited midway between the dorsal and palmar aspect; whether on the radial or ulnar border of the finger

structive tendon surgery in the palm. If the radial aspect of the palm is to be exposed the best incision lies along the course of the thenar crease. An incision throughout the length of this crease, from the radial border of the hand to the anterior carpal ligament, will expose the palmar course of the flexor longus pollicis or the flexor tendons to the index and middle fingers. It goes without saying that the corresponding digital nerves are equally well exposed. The simplest standard incision for exposing the nerves or tendons of the ring or little finger is by raising a flap. An

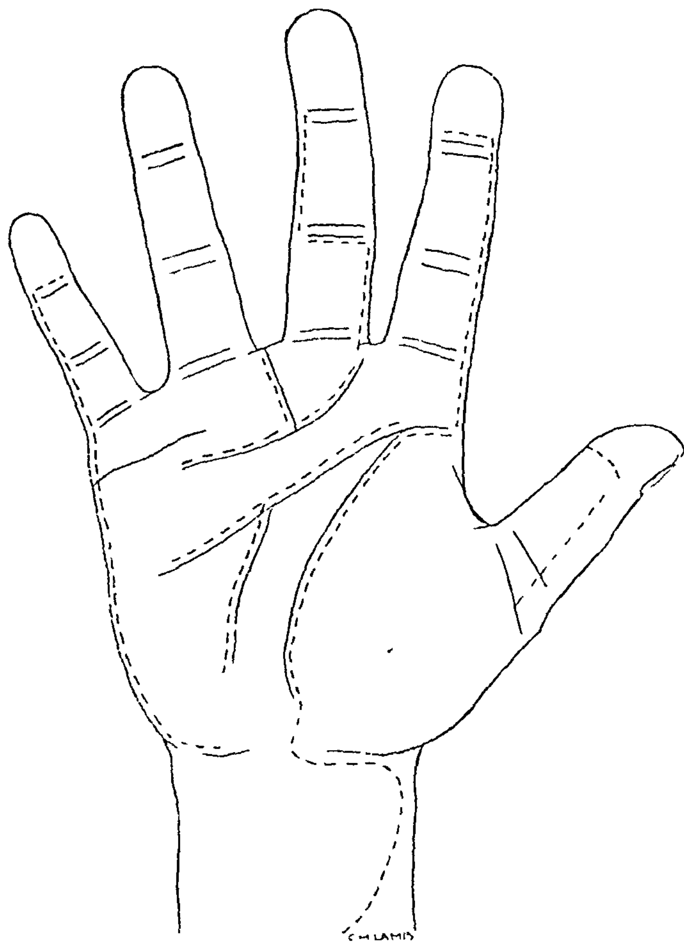


FIG 7 These conventional incisions are in common use and may be modified or combined intelligently or according to the precepts of plastic surgery, viz, the viability of any flap that is made.

incision is made, starting in the distal palmar crease, in line with the cleft between the middle and ring finger. This incision passes transversely to the ulnar border of the hand and then proximally along the medial aspect of the hypothenar eminence to the level of the pisiform bone. A flap of skin and fascia can be elevated, taking care that the digital nerve supplying the ulnar side of the little finger is not lifted with the flap as it lies on the muscles. Ordinarily the blood supply of the flap causes no anxiety but occasionally, if the transverse incision is carried rather far across the palm towards the thumb, the apex of the flap may cause a little anxiety. There is usually no more than superficial blistering.

structive tendon surgery in the palm. If the radial aspect of the palm is to be exposed the best incision lies along the course of the thenar crease. An incision throughout the length of this crease, from the radial border of the hand to the anterior carpal ligament, will expose the palmar course of the flexor longus pollicis or the flexor tendons to the index and middle fingers. It goes without saying that the corresponding digital nerves are equally well exposed. The simplest standard incision for exposing the nerves or tendons of the ring or little finger is by raising a flap. An

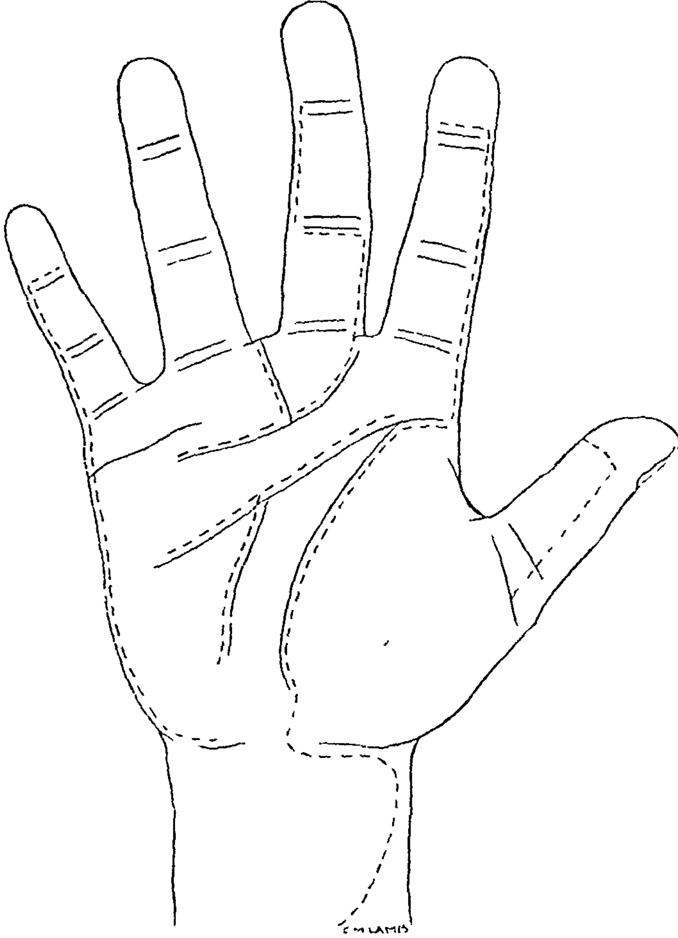


FIG. 7 These conventional incisions are in common use and may be modified or combined intelligently or according to the precepts of plastic surgery, viz, the viability of any flap that is made.

incision is made, starting in the distal palmar crease, in line with the cleft between the middle and ring finger. This incision passes transversely to the ulnar border of the hand and then proximally along the medial aspect of the hypothenar eminence to the level of the pisiform bone. A flap of skin and fascia can be elevated, taking care that the digital nerve supplying the ulnar side of the little finger is not lifted with the flap as it lies on the muscles. Ordinarily the blood supply of the flap causes no anxiety but occasionally, if the transverse incision is carried rather far across the palm towards the thumb, the apex of the flap may cause a little anxiety. There is usually no more than superficial blistering.

bulky, thick and difficult to use. Catgut at one time was used because it is absorbable but the act of absorption requires inflammation, followed naturally by abundant fibrosis and adherence. Fine silk or thread have the disadvantage of being bulky and both do, in fact, promote a small, inflammatory reaction even though they are non-absorbable. All suture materials in use had some disadvantage: whether it was related to bulk, strength or the inflammatory reaction caused. This prompted Bunnell to devise and perfect a method of tendon suture by means of the withdrawable suture technique. This particular device of suture is now not so necessary since the advent of stainless steel wire.

To-day there is little argument. Stainless steel wire is the material of choice. It can be fine and strong at the same time. It will be remembered that the finer the suture material the more likely it is to cut through the tendon tissue, as through cheese. This trouble is partly overcome by the method of suture. Fine suture material is desirable but not essential. If the wire is not highly tempered it is easy to use. It promotes no reaction; it is a versatile suture. It is readily available in two forms. As a single strand, gauges 36 and 40 are most useful but the wire must be soft and not springy. Twisted wire of three fine strands is even more malleable and easy to use and probably stronger for a given diameter than a single strand. Wire can be prepared on eyeless needles at convenience; it is boiled to be ready on the instant.

On the Method of Tendon Suture

The methods of tendon suture are infinite but the purpose is the same, that is to say to secure accurate and strong apposition of tendon ends. If part of the tendon end is not in close apposition to its corresponding aspect, adherence will develop between the bare area of the tendon end and the surrounding tissue. This is what Bunnell refers to as the unsatisfied tendon end. He has pointed out that a pseudopodium, as he describes it, attached to the unsatisfied tendon, causes firm adherence to the surrounding tissue. The surface of a tendon is covered with endothelium, that is to say a membrane designed particularly to prevent adherence between the tendon and its intimates. If this endothelium is deficient or destroyed, adherence will occur through the normal medium of blood clot growing into granulation tissue and fibrosis. An unsatisfied tendon end has no means of protecting itself against adherence. Therefore the most desirable suture is obtained where accurate co-aptation of tendons of similar diameter can be achieved. The other fact relevant to tendon repair is that stitches placed in the long axis of the tendon are apt to cut out, so that special stitches must be devised to ensure that a firm grip of a tendon in a longitudinal direction can be obtained. During the course of all methods of suture, the tendon is apt to become frayed from handling with forceps. This is all the more so if the surgeon is battling against retraction of the proximal end. Before suture is commenced the proximal tendon should be grasped with the fingers through a piece of gauze and pulled down as far

Both of these incisions can be easily extended from the palm into the forearm. The radial incision passes proximally along the course of the thenar crease to the level of the distal wrist crease. At this point it turns sharply in a radial direction until the tendons of the abductor longus pollicis are reached. The incision turns proximally along the radial border of the forearm, gradually inclining towards the flexor aspect. By this means, when the anterior carpal ligament has been divided, the whole tendinous length of the flexor tendons of the thumb, index and middle finger flexors can be exposed. This will be necessary, for instance, in the total dissection for compound palmar ganglion. The ulnar incision, designed to expose the tendons and nerves of the ring and little finger, can be extended past the wrist joint along the ulnar border of the forearm, so that when the flap has been raised the whole of the length of the tendons is exposed.

By means of the incisions mentioned the structures in the hand most often requiring surgery can be exposed without the risk of keloid formation afterwards. Casual incisions caused in the home or in the factory are most likely to be transverse in direction. The structures usually divided are longitudinal in direction, so that accidental wounds rarely give adequate exposure to the damaged tissues requiring repair. Equally, accidental incisions rarely become keloid. Accidental wounds may be difficult to modify or prolong sufficiently to undertake reparative surgery. This has a bearing on the immediate treatment of tendon injuries and will incline the surgeon to sew up the accidental wound and later to carry out restorative surgery through a planned and standardized incision designed to expose a greater length of tendon or nerve. Whether an incision should be made along the floor of the crease or parallel to the crease, say $\frac{1}{16}$ inch away from it, is immaterial. In both instances the scar will be invisible. It happens to be more easy to sew up an incision made to one side of a natural crease because the skin surface is convex and not concave.

Exposure on the Back of the Hand or Finger. On the extensor aspect of the finger, hand or wrist no great care is necessary in planning incisions. In general terms a transverse incision is better from the point of view of healing than a longitudinal one. Since the important structures run longitudinally a compromise is usually effected and a flap is devised. A direct longitudinal incision over the back of the wrist joint is to be avoided if possible. This usually does not give rise to trouble but keloid or hypertrophic scar formation on the back of the hand, though not so frequent as in the palm following a longitudinal incision, is by no means unknown. Therefore, if divided tendons have to be exposed at the level of the wrist joint it is better to make a Z-shaped incision, the oblique member of the Z passing transversely across the wrist at the level of the creases.

On the Choice of Suture Material

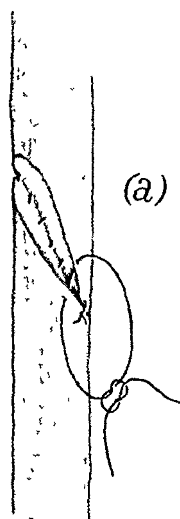
In the past there was some discussion concerning the best choice of suture material: now there need be none. Formerly strong material was

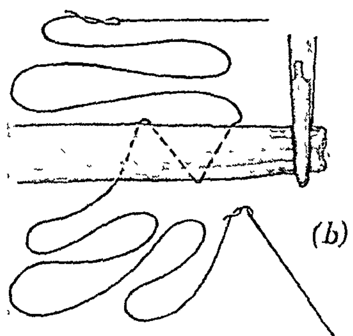
bulky, thick and difficult to use. Catgut at one time was used because it is absorbable but the act of absorption requires inflammation, followed naturally by abundant fibrosis and adherence. Fine silk or thread have the disadvantage of being bulky and both do, in fact, promote a small, inflammatory reaction even though they are non-absorbable. All suture materials in use had some disadvantage: whether it was related to bulk, strength or the inflammatory reaction caused. This prompted Bunnell to devise and perfect a method of tendon suture by means of the withdrawable suture technique. This particular device of suture is now not so necessary since the advent of stainless steel wire.

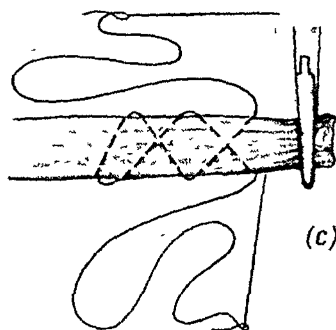
To-day there is little argument. Stainless steel wire is the material of choice. It can be fine and strong at the same time. It will be remembered that the finer the suture material the more likely it is to cut through the tendon tissue, as through cheese. This trouble is partly overcome by the method of suture. Fine suture material is desirable but not essential. If the wire is not highly tempered it is easy to use. It promotes no reaction; it is a versatile suture. It is readily available in two forms. As a single strand, gauges 36 and 40 are most useful but the wire must be soft and not springy. Twisted wire of three fine strands is even more malleable and easy to use and probably stronger for a given diameter than a single strand. Wire can be prepared on eyeless needles at convenience; it is boiled to be ready on the instant.

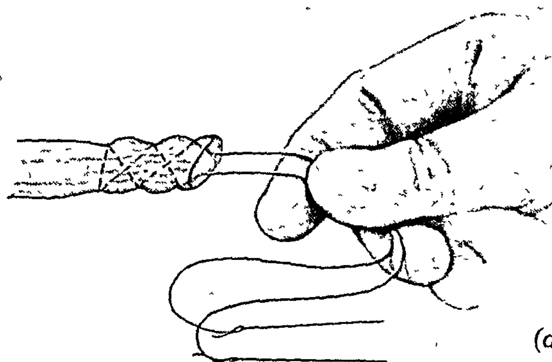
On the Method of Tendon Suture

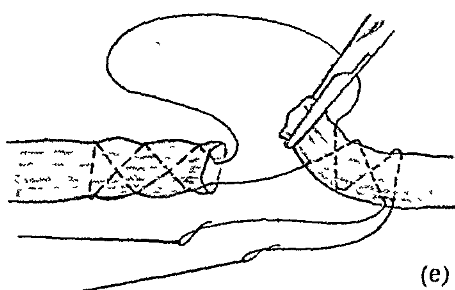
The methods of tendon suture are infinite but the purpose is the same, that is to say to secure accurate and strong apposition of tendon ends. If part of the tendon end is not in close apposition to its corresponding aspect, adherence will develop between the bare area of the tendon end and the surrounding tissue. This is what Bunnell refers to as the unsatisfied tendon end. He has pointed out that a pseudopodium, as he describes it, attached to the unsatisfied tendon, causes firm adherence to the surrounding tissue. The surface of a tendon is covered with endothelium, that is to say a membrane designed particularly to prevent adherence between the tendon and its intimates. If this endothelium is deficient or destroyed, adherence will occur through the normal medium of blood clot growing into granulation tissue and fibrosis. An unsatisfied tendon end has no means of protecting itself against adherence. Therefore the most desirable suture is obtained where accurate co-aptation of tendons of similar diameter can be achieved. The other fact relevant to tendon repair is that stitches placed in the long axis of the tendon are apt to cut out, so that special stitches must be devised to ensure that a firm grip of a tendon in a longitudinal direction can be obtained. During the course of all methods of suture, the tendon is apt to become frayed from handling with forceps. This is all the more so if the surgeon is battling against retraction of the proximal end. Before suture is commenced the proximal tendon should be grasped with the fingers through a piece of gauze and pulled down as far

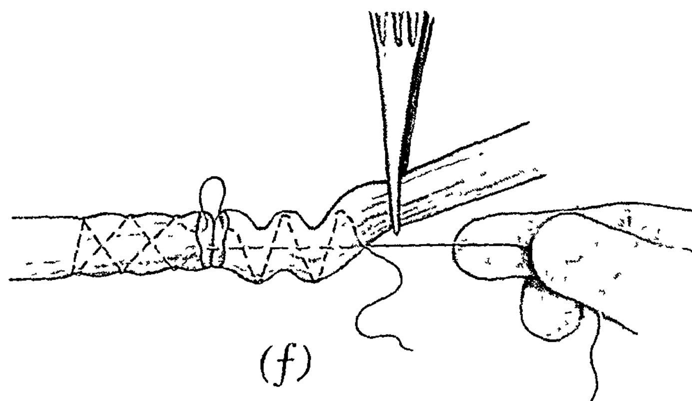

(a)


(b)


(c)


(d)


(e)


(f)


(g)

as possible and then transfixed about 2 inches proximal to the suture line with a long, straight, fine cutting needle. Tension is now removed. The ends lie snugly in apposition and ophthalmic dissecting forceps can be used to steady the tendon while the stitches are being placed.

Suture of an Oblique Tendon Division. Here the problem is not great. Simple stitches maintain a firm hold on the tendon ends when the tendon has been divided obliquely. The suture can be completed by six or more fine, stainless steel stitches around the edge of the co-aptation. The stitches are similar to skin stitches. They hold perfectly well and do not cut out and no other special devices are necessary to prevent tendon ends pulling apart. Naturally the stitches are pulled tight and the ends cut short (Fig. 8a).

Suture of a Transverse Tendon Division. A direct end-to-end suture with fine, interrupted, simple stitches is not satisfactory. The ends will inevitably pull apart. A firm hold has to be obtained on tendon tissue, at least ½ inch away from the division, so that the suture will not cut out.

FIG. 8.

(*a*) Oblique tendon divisions are not very frequent but are easy to suture.

(*b*) The steel suture is double-headed. The needles may be straight or curved but they must be triangular.

(*c*) At this stage the tendon is divided close to the forceps and both needles emerge through the cut end

(*d*) The suture is tightened.

(*e*) After the opposing end tendon has been permeated by the suture wire it is similarly trimmed.

(*f*) The suture is tightened so that the cut ends abut firmly.

(*g*) The knot has been tied. The picture has been idealized (After Bunnell.)

The technique is as follows: a length of twisted, stainless steel wire is furnished with an eyeless No. 6 curved needle at each end. One needle is passed transversely across the diameter of the tendon, ½ inch or more away from the cut end. It emerges and re-enters the tendon again, slightly forward of the point of emergence, to pass obliquely across its diameter to appear on the opposite side. Again the suture enters just forward of the point of emergence to pass obliquely across the tendon. On this occasion the needle is directed so that it will appear through the cut end of the tendon, just within the circumference. The other end of the suture is similarly passed through and through the tendon to appear also on the cut surface at a point diametrically opposite to the first end of the suture. A firm hold has now been obtained on the proximal end of the tendon. Both ends of wire are passed into the cut end of the distal portion of the tendon and made to criss-cross obliquely through the tendon in a similar manner. The needles will finally emerge on opposite aspects of the tendon. One end is passed transversely across the tendon so that both ends of the suture material appear together. The distal end of the tendon

is eased proximally up the wire lattice so that both ends abut closely and, in fact, are slightly crumpled. The suture wire is tied in a reef knot and cut off short (Fig. 8 b–g). The tightness of the knot should be great enough to bury itself in the tendon within a few days. In fact, in the final result, a very small amount of wire will be visible on the surface of the tendon. No further sutures are necessary as the hold is sufficiently strong. There are many variations of this simple technique: some designed for simplicity, some for tidiness and some according to advanced ideas about blood supply. The essential features are strong, fine material, a firm hold, a close abutment and delicate handling.

Withdrawable Suture Technique. This particular method of placing a suture in a tendon, in order to withdraw it when union is complete, was devised by Bunnell when it was felt that suture material should be removed in order to provoke the least reaction. The technique has largely lost its virtue since the common use of stainless steel wire as suture material. The method is, however, a certain means of short-circuiting muscle tension whilst union is taking place. As a mechanical method of neutralizing muscle pull, and thereby minimizing the chance separation, this technique is unique.

The first phase of the suture is similar to that already detailed. The oblique direction of the suture is to be emphasized. The suture should be commenced at least $\frac{3}{4}$ inch from the cut end. Before the second needle enters the tendon for the first time a length of suture wire is looped around it, so that when the needle has been passed through the tendon the two wires interlock. The plan is that traction on the loop of wire in due time will pull the suture out of the tendon. Except for this fact the proximal part of the suturing in this method is entirely similar to that of the foregoing. Indeed the method and direction of the suture through the distal tendon end are entirely similar, except that the two needles are directed to emerge from the same point on the surface without a final transverse stitch. Both ends of the wire now are cut from the original needles and threaded through the eye of a curved cutting needle of rather large dimensions This is directed parallel and superficial to the tendon to appear through the skin about 2 inches distal to the suture. These two ends of wire are now threaded through the holes in a button and pulled upon to draw down the proximal end of the tendon as much as muscle tone will permit (Fig. 9). The ends of the wire are twisted under this tension and cut off. The purpose of the button is to spread the pressure of the new but temporary insertion of the tendon into the skin. The withdrawal wire is now passed, proximally, by a similar method in the direction of the tendon, to emerge through the skin at a point about 2 or 3 inches proximal to the suture line. The muscle has been short-circuited into the skin and the only method whereby the suture line can be pulled apart will be by tension on the distal end of the tendon. Muscle tone or contraction cannot ruin this suture line and distal tension is prevented by correct distal posture (Fig. 10).

Three weeks after suture the tension wire is divided between the skin and the button and the ends recede into the hand. The withdrawal wire is gently pulled on. If more than a mild resistance is met with it is better to exert elastic traction for several days. This is achieved by tying

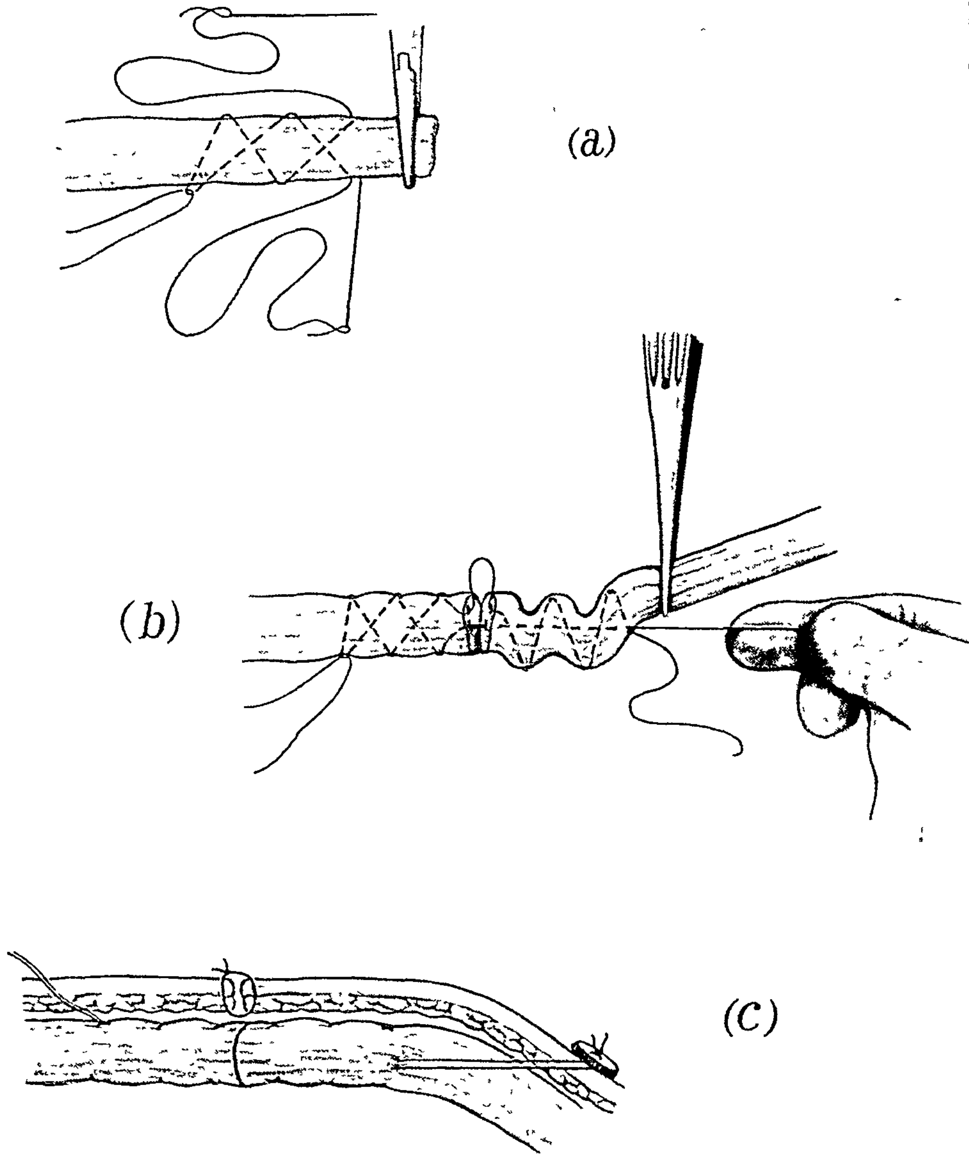


FIG 9.

(a) The pull-out loop is in position.
(b) The suture is to be withdrawn, it is as well to see that the tendon ends are mobile on the suture.
(c) The tendon has been short-circuited by insertion into the skin There is no tension on the suture line (After Bunnell)

a piece of rubber to the withdrawal wire and fixing this under tension to the flexor aspect of the forearm with adhesive strapping. The gentle pull exerted by the rubber, extending over several days, will coax the suture wire out of the tendon without possibility of any damage. When the wire

is removed there will be no suture material remaining in the tendon and the suture will be sound.

This particular method of suture by the withdrawable wire technique



Fig. 10 (*a*) The wire firmly holds the proximal tendon The withdrawal wire is to be seen.



Fig 10 (*b*) The suture is complete. The tendon is inserted into the nail. The pull-out wire is positioned.

is useful as a standard or routine method of tendon repair. It can be used for either flexors or extensors or where a palmaris or other tendon graft is used. It is most useful for the suture of tendons of similar diameter. Some surgeons consider this method of suture essential when

repairing a division of long standing. In such an instance the motor muscle will have undergone contracture and the tension on the suture line will be correspondingly greater. The short-circuit of the contracted motor to the skin can exert enough tension safely to stretch the muscle during the first three weeks. It is also used as a method of fixation of a tendon graft to the terminal phalanx. However, in this situation it is an unnecessary complication because simpler methods of fixing the tendon graft to the terminal phalanx are available.

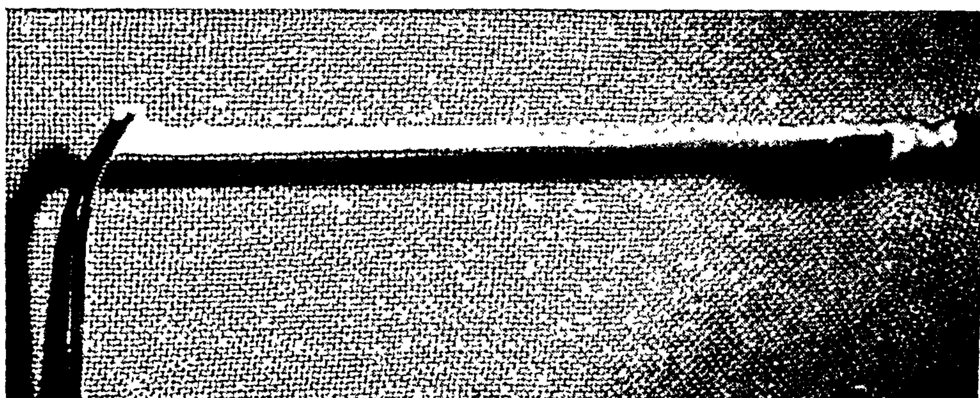
On the Method of Tenolysis

Adherence of a flexor tendon in the finger is the bugbear of reparative tendon surgery. This is especially true within the boundary of the fibrous digital sheath. Once a flexor tendon becomes firmly adherent to the surrounding tissues there is no possibility of restoring movement simply by dividing the scar tissue. After division of scar tissue it might be supposed that adherence will be less if the tendon is made to move immediately after the operation. On further reflection it is obvious that division of adhesions will be followed by a local hæmatoma and this hæmatoma is bound to organize through granulation tissue to scar tissue, binding the tendon as formerly. The conception of the use of areolar tissue as a gliding sleeve consists of making use of the mobility naturally present between the skin and deep fascia. Areolar tissue, by its loose texture, permits a certain degree of movement. If a block of tissue of sufficient depth and area is removed it might be possible to lay it round the previously adherent tendon so that the normal mobility between skin and deep fascia is transferred to the tendon, liberating it from the fixed tissues of the finger. This is the principle which lies behind the transfer of areolar tissue from the forearm to the finger in attempting to secure mobility of a flexor tendon.

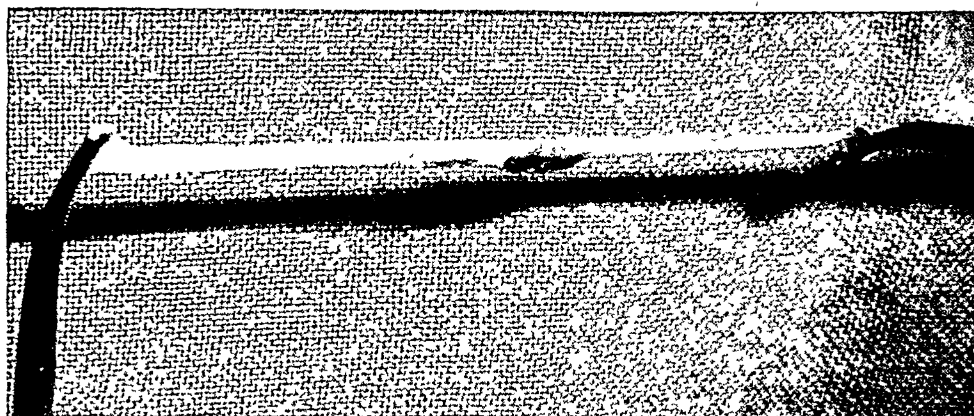
Indications. The indication, naturally, is adherence of a tendon in continuity with its muscle. This usually follows failure of a primary or delayed primary suture or a crushing injury which has not divided the tendon but which has caused so much mechanical upset and bleeding that fixation results. It is not possible to improve function due to tendon adherence caused by a thecal whitlow. The adherence is too great and the finger is almost always stiff and atrophied. One pre-requisite of any improvement resulting from the use of areolar tissue is ability to use the muscle concerned and free passive mobility of the joints which would be moved by the tendon. The timing of a tenolysis is important. If the procedure is carried out when the finger is swollen and tender the result is not likely to be good. If the finger is passively mobile and shrivelled and painless, then tenolysis is more likely to be successful.

Procedure. More than the adherent part of the tendon has to be exposed. It is approached according to standard procedure, depending on its site. Usually there will be scars of previous injury or surgery. The skin incision may have to be modified to include or avoid previous scarring

so as not to jeopardize skin viability. The extent of adherence is immediately obvious as the appearance of an adherent tendon is characteristically different from the appearance of a tendon normally mobile within the digital sheath. When the length of involved tendon has been measured, the areolar tissue to be transferred is exposed. Probably the best quarry for areolar tissue in this instance is to be found on the volar aspect of the forearm. Naturally the forearm of the same side will be used as it will already be bloodless. The skin is divided longitudinally and dissected



(*a*)



(*b*)

FIG. 11 (*a*) and (*b*) The palmaris longus tendon is held up. The difference in position of the small fragment of muscle denotes the excursion of the paratendon.

from the subcutaneous tissue over the necessary area. The area of tissue to be removed is staked out by the tips of four fine artery forceps. A quadrilateral incision is made through the areolar tissue indicated by the forceps and it is then separated from the deep fascia by horizontal strokes. The forearm incision is sutured. The fascia is immediately wrapped around the affected length of tendon. It will tend to contract. The tube of areolar tissue is anchored at either end to the static tissue of the finger by fine steel sutures. The edges of the tube are sutured by a continuous length of wire of fine gauge and so arranged that the ends emerge from the

skin continuing the general line of the seam. The ends are clamped by split lead shot permitting the whole length of wire to be removed in three weeks (Fig. 44).

It is useless to expect a long length of adherent tendon to become mobile immediately it has been surrounded by areolar tissue. Tendon readily becomes necrotic. The use of areolar tissue is only of value when the adherence is of limited extent. It is of proven value as a routine measure during the course of a secondary tendon suture. It is equally



FIG. 12. After suture the join will lie in the digital sheath where adherence is likely The rounded proximal end invites the suture line into the palm. A free tendon graft is indicated

of value during the course of a secondary lysis operation after failure of a primary or delayed primary suture. It is of less value following adherence from crush injuries and of no value for fixation following infections.

On the Technique of Free Tendon Grafting

The conception behind free tendon grafting is as follows: the indifferent results following tendon suture in the finger are due to adherence of the tendon and suture line to the surrounding fibrous sheath. The distal end of a divided tendon is apt to become adherent along its length as the smooth endothelial layer of cells degenerate from disuse. Adherence

far as possible. A tendon stripper of appropriate diameter is passed over the tendon and forced proximally over the middle phalanx as far as is necessary to sever the adherence of the distal fragment. If the tendon is grasped in forceps and held taut the stripper passes easily. The amount of tendon removed will depend on the situation of the original cut.

If the proximal ends of both tendons are lying in the palm, the proximal digital sheath will be obliterated by proliferation of the endothelial lining. A passage will have to be made through the obliterated lumen of the sheath



FIG 13 (*a*) The distal end of the profundus has been exposed and is exhibited The distal end of the sublimis is about to be removed. The rounded proximal tendon end is visible in the palm.

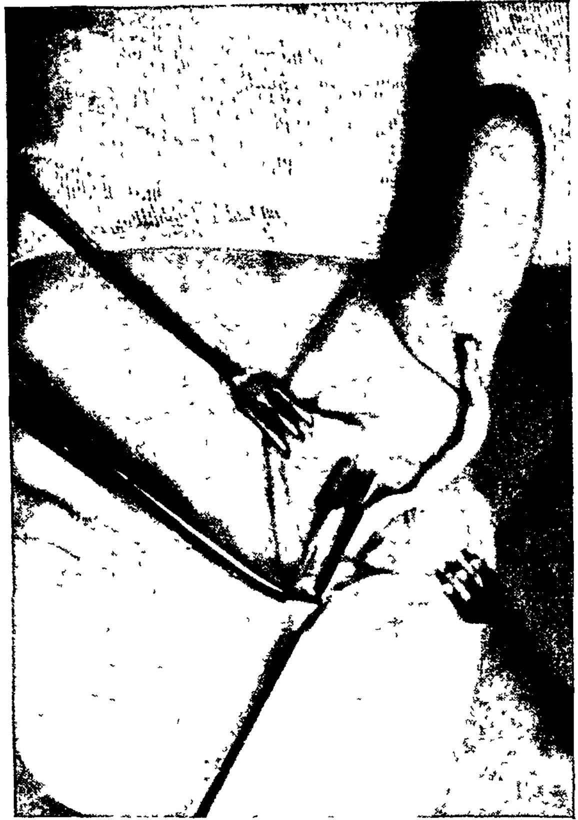


FIG. 13 (*b*) The divided profundus had retracted into the palm and was not adherent. The sublimis was not divided and is being removed by a tendon stripper.

but first of all the stump of the sublimis tendon may have to be removed. If the original cut in the finger is at the level of the proximal interphalangeal joint the stump of the sublimis tendon will be insignificant and need not be removed. If the original wound is proximal to the joint, a stump is present and must be exposed by prolonging the longitudinal limb of the terminal incision until the insertion of the sublimis tendon is found. This is divided and the tendon stump is removed (Fig. 13a).

If the proximal tendon ends have not retracted and still remain in the digital sheath, they will have to be removed through the palmar incision. Sometimes, for instance, the sublimis tendon is not divided completely,

though it may be inactive because of scarring. Often the profundus tendon has retracted into the palm, though the sublimis remains in the finger (Fig. 13b). Sometimes, also, after a complete division the profundus is restrained from retraction by an abnormally strong vinculum longum. The tendon adherent in the finger is divided in the palmar wound and a stripper is threaded over the end and passed distally. The stripper is forced on until the tendon comes away. If both tendons are adherent the manœuvre is repeated. By this means all tendon is removed



Fig. 14 (*a*). The palmaris is exposed and ready to be removed without its paratendon.



Fig. 14 (*b*) The graft is being led through the digital sheath by the hooded probe.

and a passage can now be forced along the finger with a malleable probe, keeping it as close to the phalanges as possible. The proximal end of the sublimis tendon is pulled on and divided high up to rid it from the wound. Now the finger is prepared to receive the graft.

An incision is made from the anterior carpal ligament to the upper third of the forearm in the mid-line. The distal end of the palmaris longus tendon is identified as it emerges into the fibrous tissue of the carpal ligament. It is divided, grasped in forceps and lifted. The tendon is removed to the musculo-tendinous junction by longitudinal sweeps of a

sharp knife a $\frac{1}{4}$ inch on either side of it (Fig. 14a). The skin is sutured with a continuous stitch of fine wire.

A probe is passed from the palmar incision along the finger. The palmaris graft is held into the trailing end of the probe by a catgut stitch and drawn through the finger (Fig. 14b). The cut or free end of profundus tendon is grasped by forceps and pulled longitudinally to stretch the muscle. With the muscle in tension the tendon is transfixed in the palm so that it will not retract. It is then divided a $\frac{1}{4}$ inch distal to the origin of the lumbrical muscle and split longitudinally across its diameter for $\frac{1}{2}$ inch. The ends are slightly bevelled from within outwards. The proximal end



FIG. 15. The exercise is complete The forearm and digital wounds are sutured. The graft is secured to the nail. The annularis lies a little more flexed than is normal The palmar wound is to be sutured.

of the free tendon graft is placed within the alligator jaws of the profundus tendon and the two are sutured together with fine stainless steel wire. Two transverse mattress stitches only are required. It is possible to bury the suture line by wrapping the lumbrical muscle around it. This will further help to prevent local adherence. The palmar skin incision may now be sutured.

All that now remains to be done is to fix the distal end of the graft to the distal phalanx in the correct amount of tension. A method of fixation is as follows: a Kirschner wire is passed through the distal phalanx a $\frac{1}{4}$ inch beyond the joint line to emerge through the nail. Through this hole a straight cutting needle is passed bearing No. 2 chromic catgut. The end of the needle is now passed four or five times through the graft to obtain

a hold. A similar hole is bored on the other side of the volar aspect of the phalanx to emerge in a corresponding position in the nail. The needle is now passed through to emerge through the nail. The ends of the catgut are tied over the nail with an effective knot which will not come undone. By the time the chromic gut has been absorbed and the knot comes away the tendon end will be firmly adherent to bone.

Judgment of the correct length of a tendon graft is an art. To assist in deciding the correct length to be used the hand is allowed to lie supinated on the operating table, with the fingers taking up the normal position of repose. The hand lies in a position of ulnar deviation with the fingers flexed in diminishing amount from the fifth to the index, with the thumb in a position of easy adduction. The basic length of graft is that length which will hold the finger in the appropriate relationship with its neighbours. When this amount has been determined the length should be reduced by ½ inch or more, depending on the interval between injury and grafting, so that when suture is complete the finger is lying slightly more flexed than it should do (Fig. 15). This is probably the simplest method of determining the correct length of tendon that should be used. If a measurable length of the profundus tendon can be removed and measured a graft of correct mathematical length can be used. It has been said by some that free tendon grafts are liable to contract. It hardly seems that this is correct. Rarely, if at all, does one see disability after tendon grafting which can be accurately referred to shortness of the graft.

The question arises as to which of the two possible motors should be used to activate the free tendon graft. The profundus muscle is the obvious choice because it has a greater excursion than the sublimis. Furthermore, the suture line can be made close to and partly encased in the lumbrical muscle so that it will lie in areolar tissue with no possibility of adherence. The profundus muscle is peculiar in that it behaves as though it were really one muscle with four tendons arising from it. There is little or no separate action between the muscle slips. It is not possible to contract the profundus muscle to one finger without stimulating the others. If there has been an interval of perhaps six months between division of the tendons and grafting, it may be found that the excursion of the profundus tendon seems much reduced. The reason for this is that if the tendon has retracted into the palm the corresponding portion of the muscle will have been continually shorter than its normal resting length. It has been found by Blix and others that if a muscle is continually stimulated whilst at its resting length, or shorter, it will undergo myostatic contracture which will ultimately become irreversible. A muscle in such a state is no longer capable of its normal lengthening (see Chapter 6).

It seems that the sublimis muscle is different in its nature from the profundus and that if a sublimis muscle and tendon lies for some months shorter than its normal resting length it will not undergo such severe myostatic contracture. The sublimis muscle is more differentiated and capable of individual contraction, so that the normal use of the other

digits does not stimulate the affected muscle slip and so provoke contracture. At all events, it is found on examining the excursion of the motors of the digit, the tendons of which have been divided for six months or more, that the sublimis muscle has a greater excursion than the profundus. In this case it is advisable to sacrifice the profundus from the level of the lumbrical origin and use the sublimis muscle as the motor for the graft. When the profundus tendon has been divided in the finger the lumbrical muscle prevents wide retraction. It will be found that with the metacarpo-phalangeal joint held fully extended the terminal two joints cannot be passively flexed fully, denoting intrinsic tension, in this instance due to the pull of the retracting profundus.

If the profundus has been divided above the lumbrical muscle the retraction may be very wide indeed. The myostatic contracture is extreme and the muscle becomes quite useless for further use in a few months. These conditions and restrictions and suggestions do not apply in the case of failed previous suture, since in this instance the muscle will be lying at its normal resting length or longer. In such an instance myostatic contracture does not occur.

On the Use of Pulley Making

The function of the fibrous sheath in the finger is twofold. Firstly it holds both flexor tendons close to the phalanges. The second function of the digital sheath is to protect the tendons from mechanical irritation. Traumatic tenosynovitis is unknown in the fingers, whereas it is relatively common in, for instance, the extensor longus hallucis tendon, from pressure of a shoe; or the tibialis anticus from pressure of a boot.

Over the proximal phalanx there is a thickening of the fibrous sheath. This thickening, designated the proximal pulley, is important. At the proximal interphalangeal joint the fibrous sheath is very much thinner because it has to buckle during the normal range of flexion at that joint. Over the middle phalanx the tendon sheath is present and strong but it does not have to be as effective as the proximal pulley, because the insertion of the profundus tendon does not deviate far from the axis of the middle phalanx, even in considerable flexion. The proximal pulley is the more important and this may have to be reconstructed if it has been destroyed by disease or injury. Such a pulley is only effective and necessary during pinching between the finger and the thumb. During the action of grasping, as, for instance, an oar or a broomstick, the object grasped holds the tendons into their normal situation. Therefore the absence of a pulley is more likely to be a disability to a fine worker, a writer, a violinist or a typist, rather than the heavy manual labourer.

The pulley may be damaged by the original injury or it may be damaged during the course of a tendon suture if its division is necessary. The pulley is very frequently found wrecked during a free tendon grafting which follows previous attempts at reparative surgery which have failed.

A diagnosis of a deficient proximal pulley is so obvious that it need

not be mentioned in detail. The deficiency is not always a disability but if it is an attempt should be made to remedy it. No attempt should be made to restore the anatomy of a pulley unless the tendon is working freely and the surgeon can convince himself that the patient suffers disability from absence of the restraining effect of the proximal part of the tendon sheath.

The proximal part of the finger is exposed either by two lateral incisions or by means of a flap. The appropriate method will largely be determined by the presence and situation of scars of previous surgery. A length of deep fascia, 2 inches long and ½ inch wide, with superficial areolar tissue attached, is removed from the forearm. This is passed through one incision in the finger over the tendon, deep to the skin, and brought out through the opposite incision. One end of the fascia is then sutured to the fixed tissue on the lateral aspect of the proximal phalanx throughout its width. The fascia is then pulled as tight as suitable and a similar suture or junction is made on the opposite side. The incisions are sewn up and the dressing compresses the finger, holding the tendon firmly against the phalanx for three weeks. The finger may be used before that time but it is important that the fibrous tissue should be given every chance of union by being relieved of strain during this time. No reconstruction of the fibrous sheath over the middle phalanx is ever necessary.

On the Closing of the Skin and Release of the Tourniquet

Some surgeons after operating on the hand sew up the skin without tying any vessel. They apply a contour dressing snugly over the wound and release the tourniquet. It is claimed that there is no bleeding afterwards and that a hæmatoma does not accumulate. Others are not convinced about this and do not feel easy in their minds unless the tourniquet is released before the wound is sewn up so that the major bleeding vessels, to say the least, can be identified and ligatured. The theory behind this latter method is that no dressing can, by its pressure, prevent a divided artery from bleeding into the tissues. The superficial palmar arch must almost always be divided during an exploration of the palm. Surgeons who release the tourniquet before wound suture believe that post-operative bandage compression can be reduced without risk of œdema of the tissues and accumulation of blood in the wound.

When the blood pressure cuff is released the wound fills with blood in a rather disconcerting manner and although certain blood vessels can be identified and ligatured, this does not seem to affect the total amount of bleeding very much. If the surgeon then messes about for a quarter of an hour or so to satisfy himself that no major bleeding continues, he will create another problem. During the time taken in attempting to stop bleeding the tissues become œdematous, because of capillary permeability following anoxia. The wound is then difficult to suture neatly and the bandage will be applied to an already œdematous hand and finger. Furthermore, the possibilities of infection are increased if the area of the

wound is soaked in blood. In general, dry areas can be considered to be less contaminated than wet areas.

The matter must be left to the choice of the individual surgeon. It seems, however, that the advantages to be derived from releasing the tourniquet before suture are outweighed by difficulties and potential dangers. Suture of a wound under a tourniquet, followed by the application of a contour dressing under moderate compression by a crepe bandage, is entirely satisfactory in practice. Hæmatoma does not form and tissues do not become œdematous, though possibly the patient suffers more discomfort in the first two or three days after operation than he does if the compression is less severe, as it can be if the tourniquet is released before suture. Sedatives fulfil their purpose.

The wound itself is sutured by interrupted stitches of 40-gauge stainless steel wire, or its equivalent in twisted steel wire. The suturing must leave nothing to be desired. It is *haute couture* whereby the incision, if properly placed, is rendered almost invisible. Those placed longitudinally in the forearm are always visible and are apt to spread.

On Dressing the Wound

The purpose of the dressing is to exert compression on the tissues which have been damaged by the operation and devitalized by anoxia due to the tourniquet. The dressing also excludes infection penetrating from without. It is not intended to absorb blood or pus in the general surgical manner. The dressing to be applied is known as a contour dressing because it is accurately moulded to fit the contours of the palm and finger. The best material for this purpose is cotton wool and it is soaked in a sterile fluid to make it malleable. Two fluids are popular: Cremor proflavine B.P.C. or water. Probably the flavine in paraffin is the better of the two because it is not aqueous; moisture is liable to breed infection.

Pressure must be applied throughout the operated area and the wool moulded to fill out the concavities so that a circular crepe bandage will exert uniform compression throughout. It is difficult to bandage a finger adequately and so sometimes it may be felt necessary to bandage the whole of the hand and fingers in a boxing glove manner. A layer of wool must be put in each cleft between the fingers, which are then allowed to assume a relaxed attitude. Sufficient wool is put in the concavity of the fingers and a thin layer over the convexity and the whole is bandaged as though in a boxing glove; but the tip of each finger must be visible so that the circulation can be checked after removal of the tourniquet.

It will often be found, after removal of the tourniquet, that the finger which has been operated on remains bloodless for several minutes after the blood supply of the other fingers has evidently returned. It is not possible to apply a crepe bandage over wool sufficiently tightly to act as a tourniquet but after prolonged surgery the digital vessels remain in a state of spasm which may not relax for some minutes after release of the blood pressure cuff. No anxiety need be felt following normal surgery

if the finger fails to regain its colour as soon as the others do. Occasionally it may be necessary to hold the hand in a dependent position deliberately to cause congestion. Rarely should the bandage be loosened and re-applied; the blood supply is always restored without serious difficulty.

After an operation involving exsanguination for an hour or more the hand is bound to be painful and congested as the result of anoxia. The patient's comfort can be increased if the hand is elevated for forty-eight hours. The circulation is quick to regain its tone, and œdema due to permeability of the capillaries rapidly reduces itself. On nearly all occasions the compression bandage should be left *in situ* for three weeks without release. It is then certain that no œdema remains beneath and that healing has progressed sufficiently to ensure that the tendon suture line will not part under the gradually increasing stress put upon it by reconditioning.

On When and How to Suture a Nerve

It might be thought that there could be no argument as to the optimum time for nerve suture. Clearly the prerequisites of surgery must be satisfied, that is to say absence of wound infection and the mechanical possibility of co-aptation, but opinions differ as to whether the nerve should or should not be sutured immediately after division. Until recently it was general policy to suture a nerve at the earliest possible moment. A nerve found divided when a laceration of the wrist was being explored was almost always sutured, however unsuitable the surgical surroundings or inexperienced the surgeon. The results generally of that type of suture are not good. It was found, however, that the results of immediate nerve suture, when done by experts in a Peripheral Nerve Unit were too capricious to be acceptable.

Seddon and his collaborators, as a result of a very extensive wartime experience, have stated in general terms that the results of secondary nerve suture are better than those of primary. Late exploration of an unsuccessful primary suture often reveals a correct end-to-end suture but with a central, fusiform neuroma immediately proximal to it. The appearance suggests that intra-neural damage to the nerve, not recognized at primary suture, blocks the passage of regenerating axones before they reach the suture line. Bewildered, they form a confused mass and fail to pass into the distal portion in sufficient numbers to give a good recovery. This unseen axon damage can be removed if the proximal end of the nerve is pared with a sharp knife at the primary suture. But how much should be removed? The obvious limitations make this method unattractive to the practical surgeon. The bulk of peripheral nerve surgical knowledge is based on experience with gunshot wounding, or at least blunt injury. The accurate assessment of the extent of nerve damage is almost impossible, except in razor wounds.

As a result of this experience it has been found that the best immediate treatment of a divided nerve is co-aptation of the ends by a single stitch

in correct axial rotation. The correct correspondence of rotation can more easily be judged when the injury is fresh. Co-aptation by a marker stitch will ensure the possibility of correct rotation at secondary suture. The proximal end bulb matures slowly. Suture must not be undertaken too soon. Usually eight to twelve weeks are necessary for full maturation, so that, at inspection, the neuroma can be accurately defined and removed without unnecessary sacrifice of nerve length. It is bad practice, as well as being pointless, to carry out a primary suture in the hope of success. By the time it is realized that there is no recovery, the optimum time for nerve suture will be passed. The inhibition against immediate nerve suture does not apply in instances when the nerve has been cleanly divided with a knife, as in a surgical operation. There is no undefined proximal damage in this instance and suture can be carried out without fear of a proximal central neuroma developing.

Nerves are apt to be divided in a haphazard geographical distribution, that is to say it is an injury almost as much of the home as of the factory. The necessary skill accurately to suture divided nerves is available only in widely scattered centres. It is advisable that the patient should be treated by those particularly skilled in the technical manœuvres of nerve suture. If, therefore, the word goes out that delayed suture is desirable, the delay of several weeks will permit the patient to be transferred from a place of inadequate surgical skill to a Peripheral Nerve Centre where the necessary experience is available.

The Technique of Nerve Suture. During the first world war it was found that the best suture material for a nerve trunk should be fine, strong and non-absorbable. The masters of that day selected greased, linen thread No. 160. Absorbable sutures were found to promote an unnecessary reaction which increased fibrosis, probably diminishing conduction afterwards. In most instances of peripheral nerve surgery it is evident that the limiting factor is human skill. A nerve trunk is difficult to handle; it is apt to fray; the neurilemma is fine, tends to retract and stitches pull out if under tension. During the second world war other methods of nerve union were tried. For instance, the nerve ends were held in close apposition by fixing stitches to the muscle and then local adherence of the nerve ends was secured by bathing them in chicken plasma which, when coagulated, lightly but accurately bound the ends together. This technique was tried experimentally and soon given up as the difficulties encountered were not offset by advantage of enhanced recovery. Autogenous plasma was later developed and is still used sometimes for nerve grafting.

It is clear that the surgeon has to rely on his own skill in nerve suture. New suture materials are now available and generally it is agreed that fine, malleable, stainless steel wire is the best obtainable at the moment. The wire is very fine; it is very strong for its diameter and it is entirely inert. The first prerequisite to a successful suture is that there must be no tension on the nerve ends. If some portion of the nerve has been lost,

or if the nerve has to be significantly trimmed because of fibrosis which has developed, some means must be used to produce sufficient length to enable a suture to be made without tension. In the ulnar nerve, for instance, this is an easy matter, because transposition of the ulnar nerve to the front of the elbow will allow a surgeon to close a gap of more than an inch at the wrist. If an ulnar nerve division at the level of the wrist is not sutured for three months, it is almost certain that a transposition of the nerve at the elbow will be advisable to avoid tension. In the case of the median nerve it is possible to gain some length, if necessary, by division of the bicepital fascia at the elbow. When this is done the nerve can be mobilized in the forearm and up to 1 inch in length can be gained at the wrist. It is not wise to relax the suture line by pronounced flexion of the wrist. When in doubt, necessary length is to be obtained by formal mobilization.

When no tension remains, suture proceeds. All possible efforts are made to prevent axial deformity of the nerve ends. They are brought together by fine, stainless steel stitches through the perineuron, using perhaps six or eight such sutures. If they are accurately placed there is little difficulty in obtaining a satisfactory anastomosis. When the best suture that can be obtained in the circumstances is complete, the nerve is laid back in its bed. The degree of extension of the wrist that first puts tension on the suture line is noted before the wound is closed. If restraint is necessary, on account of tension developing at the suture line, a splint should be applied for at least three weeks, after which time gradual restoration of movement in the joint, without force, may be permitted. Considerable care is necessary to ensure that the suture line does not separate if suture has to be carried out under tension.

It must be remembered that regeneration after nerve suture is a slow process. It is not very wise to quote to the patient the popular figure of 1 mm. a day as the rate of growth. The patient will estimate, by complicated and inaccurate mathematics, the probable day of recovery and will be disappointed at any delay. If the median nerve is divided at the wrist, even in the best circumstances, it may be more than three months before the first flickers of motor activity are noticed in the thenar eminence. Similarly with an ulnar nerve division at the wrist, it may be an equal time before any activity is noted in the hypothenar eminence. Sensory innervation accompanies the motor and gradually there will be a diminution in size of the anæsthetic area. First, appreciation to deep pressure will be noticed and then pinprick will be recognized as a sensation of pressure and imperfectly localized. Pinprick may be noted as an unpleasant, ill-defined, spreading sensation and at this time probably there will be hyperidrosis over the area supplied by the nerve. The last sensation to return is appreciation to light touch. It is unlikely that normal sensation will ever be fully restored; that is to say two-point discrimination will always lack some finesse.

The old masters were apt to consider a tourniquet as anathema in

nerve surgery. It was regarded as unsporting to have a bloodless field: it was thought that a post-operative hæmatoma was more frequent after use of a tourniquet. While it is probably true that in general peripheral nerve surgery it is best not to use a tourniquet, it is equally true that any surgery in the region of the wrist and the palm is too difficult in any but a bloodless field.

CHAPTER 3

INJURIES OF THE SKIN

Lacerations not involving Deeper Structures

Cuts of the fingers or hand are the most frequent of all injuries. The majority of these do not require surgical treatment. They are dealt with by the patient and they quickly heal without disablement and usually with insignificant scarring. This is the more remarkable because almost always the skin of the hand is heavily contaminated. Moreover the natural impulse to pop the finger into the mouth when it has been cut is almost



FIG. 16. Most cuts on the hand are trivial. They merit accurate suture usually without marginal excision.

irresistible. This ensures that the contamination is heavy and prolific. In spite of this healing takes place, usually by first intention. It is to be inferred, therefore, that like the scalp, the skin of the finger is able to look after itself, probably because of its ample blood supply. Not every incision, however, heals by first intention. A linear cut across the volar aspect of the finger, in close relationship to one of the creases, may take more than a few days to heal. Such a wound is apt to become quite troublesome and indolent. The only difference between a larger and a smaller cut, involving skin alone, is that the former should be sutured. More extensive lacerations are considered with greater seriousness and their treatment involves inspection of the deeper tissue to determine the extent of the injury. A simple laceration of skin requires suture, only if the tissues do not lie closely opposed.

In time past a patient presenting himself in the Casualty Department of a hospital with a cut finger was first instructed to steep it in diluted hydrogen peroxide for several minutes. Then an inexperienced casualty officer or sister proceeded to suture the wound using a barbarous needle, thick salmon gut and no anæsthetic. These days are, or should be, passed. If an incision requires suture it should be well sutured and for this purpose an anæsthetic is necessary. The terminal two sections of the finger can be adequately anæsthetized by a digital nerve block made at the web (see p. 19). A cut extending to the base of the finger cannot be anæsthetized by this technique; the surgeon may then consider an ulnar or median block at the wrist. In certain circumstances a brachial plexus block may be desirable (see p. 18).

When the part is anæsthetized, the wound is swabbed with detergent solution followed by alcohol. If, after a brief inspection without a tourniquet, it is considered that the cut is only superficial it is sutured carefully, using fine curved cutting needles and fine suture material. The edges are accurately approximated, ensuring that the scar will be almost non-existent (Fig. 16).

For more extensive lacerations of the fingers and palm, the surgery of suture must be more formal. Extensive laceration by machinery or by glass is very liable to be complicated by damage to the deeper structures. It may, on occasion, be difficult to recognize damage to the deeper structures without elaborate inspection. A tourniquet, therefore, is necessary. A tourniquet is applied around the base of the finger after a digital block and the wound can be fully examined. Similarly, after a brachial plexus block, an examination of a more extensive laceration can be carried out. If there is reason to suppose that the laceration has extensively involved the deep tissue, it is wise that the patient should be admitted to hospital so that exploration may be unhurried and complications anticipated.

Experience in two World Wars has impressed surgeons with the necessity to excise skin edges in instances where there has been laceration in conditions of contamination. It is possible that in certain instances the pendulum has swung too far. The purpose of skin edge excision is to remove that tissue which, by injury and contamination, is rendered incapable of looking after itself. The ability to heal *per primam* depends on an adequate blood supply in relation to the amount of contamination. These factors are complementary. The skin of the hand, like that of the scalp, is so freely supplied with blood that in spite of heavy contamination healing readily takes place without development of frank infection. If, however, the blood supply has been jeopardized by injury, the skin may be unable to cope with contamination and in this instance the edge should be excised. The only skin edge in the palm or fingers which should, in fact, be excised is that skin which is evidently mechanically damaged. In a simple laceration the damage to the skin is slight and excision of the edge is unlikely to be necessary and should rarely be done.

Some lacerations by their direction and extent may jeopardize the

vitality of a flap so formed. To judge the vitality of a flap at the time of primary surgery is difficult. If the blood supply is almost non-existent, the skin is thereby transformed into a Wolf graft. Such a flap, to survive, must have no fat on its deep surface, must lie on a vascular bed and must not be too extensive. It is remarkable to what extent skin of the fingers, with an inadequate blood supply, can survive if no hæmatoma collects beneath. Avulsion of skin and degloving injuries of the back of the hand are often severe in nature. A reversed flap of large area on the dorsum of the hand is apt to become necrotic because it can only drain into and receive nourishment from a distal part that is itself embarrassed because the venous return has been blocked (Fig. 17).



FIG. 17 (*a*). This distally-based skin flap was of doubtful viability and it was replaced. The gamble did not come off.



FIG. 17 (*b*) On the fourth day the whole of the original flap was replaced by a free graft although not all of it was manifestly dead.

Even though the surgeon is aware of all the pitfalls and catches, he may find it impossible to know if a flap will survive or not. When doubt exists, the flap should be replaced and watched closely in order to judge its state, so that at the first evidence of necrosis it can be replaced by a free graft. When there is fat lifted with the skin, it should be pared off with scissors before the skin is replaced, because the chances of survival are much greater.

After all blood clot has been removed, the skin is replaced and suture commences. Fine cutting needles of appropriate size are used. Probably the best all-round suture material is fine stainless steel wire. Many stitches are used. They must be sufficiently tight to approximate the skin edge without strangling the blood supply.

Dressing the Wound. If a large flap of skin has been raised a potential space is created in which a hæmatoma can form. It may be necessary to apply a pressure dressing for twenty-four or forty-eight hours after suture of such a laceration. Explorative surgery which requires skin elevation must have a similar pressure dressing applied afterwards. Often, however, some hours elapse between the injury, that is to say, division of the blood vessels, and suture. In these instances a hæmatoma does not usually collect afterwards because the primary surgery consists only of evacuation of blood clot and suture of skin. Therefore, except in instances where there has been extensive skin elevation, a pressure dressing may not be essential after suture of a laceration.

Infection is prevented from entering the wound by using a sealing compound. In all lacerations not requiring pressure Whitehead's varnish or Norbecutane may be used. These preparations are attractive to apply and they permit complete sealing of the wound. The finger is under vision and early movement is possible without the restraint of a dressing and bandage.

Palmar wounds always require a contour dressing for forty-eight hours to prevent bleeding, after which the dressing is removed and the wound is sealed. The advantages of this method of treatment are obvious. Movement, usually desirable, can be instituted at the earliest possible moment, thereby minimizing stiffness in the joints. If the patient is unable or unwilling to take advantage of the liberty given him by the varnish dressing, hypostatic œdema will cause the fingers to stiffen. If this is the case a pressure dressing should be re-applied as soon as the decision is taken. Cotton wool should be moistened with Cremor proflavine. Its malleable state permits it to be moulded to the contours of the finger and palm. Compression can be applied by means of a 2-inch crepe bandage. The swelling is controlled, and when pressure is removed in ten days stiffness of the fingers will not be great. Fingers which have not been compressed and allowed to swell are much more difficult to mobilize.

Crushing Injuries

The essential feature of a crushing injury is the effect of the crush on the tissue. There may be much evident damage, but in addition there will be considerably more that is not evident but which will be equally provocative of post-traumatic œdema. The surgeon, therefore, should assume that the hand is a good deal more injured than at first seems apparent.

Extensive injuries occurring in the machine shop or on the roads are for the most part crushing in nature and often complicated with traumatic amputations and compound fractures. In this chapter our concern is with the skin. The assessment of the damage is often difficult. After a brief look at the degree of wounding in the Casualty Department, the patient is admitted to the hospital and the detailed inspection of the damage is carried out in the theatre. The patient is anæsthetized and the





FIG. 18 (*a*). In a severely crushed hand the fractured metacarpals are of small importance.





FIG. 18 (*b*). The skin was replaced after excision and the fractures were controlled with wires. Fortunately the skin flap survived.

hand is liberally washed with detergent solution and spirit. The arm is held up for several minutes and a blood pressure cuff, already placed above the elbow, is rapidly puffed up to 300 mm. of mercury. When towels have been laid and the surgeon comfortably seated before the draped hand, the scene is set for inspection of the wound and assessment of the injury. In injuries of this nature, when the extent of the damage has to be determined at the time of operation, it may be necessary sometimes to enlarge a skin wound to complete the examination. It is not appropriate at this time to undertake reparative surgery. All the surgeon is able to do is to gain information of the extent of the damage, remove the tissue which is



FIG. 18 (c). Now the hand is fit for replacement of the extensors to the long, ring, and little fingers

damaged beyond hope of functional recovery and secure skin cover. Closure of the skin is the first essential if the formation of granulation tissue with subsequent and inevitable fibrosis is to be avoided. Occasionally a simple method of internal fixation may be used for the accompanying fractures (Fig. 18), but tendons are not sutured.

There may be massive tissue death in hands injured by crushing. To determine the extent of the necrosis may be very difficult and quite impossible in a bloodless field. As an aid to inspection exsanguination is necessary. To determine viability of tissue the blood pressure cuff must be removed. Crushing wounds may require excision of damaged skin edge but this should be as sparing as possible. Probably the super-

ficial layer of skin will be separated from the dermis in parts. This should be removed permitting approximation of the dermis. The dermis may be soggy and soft, accepting stitches badly so that they are apt to cut out. Where excision is not carried out, suture is almost always feasible in spite of the irregularity of the laceration. More often than might be supposed it is possible to avoid wound excision without reaping a desperate reward of infection.

When the wound has been sutured, with drainage if appropriate, compression must be applied. The compression must be firm. Any form of external splintage should be avoided if possible as a splint is liable to prevent compression from being effective. Most fractures can be relegated to second place in an injury of this sort. Compression should be exerted (see p. 43) in an appropriate way for from three to five days, and then the dressing should be removed. The oil of the Cremor proflavine is removed with spirit, the drains, if any, withdrawn and the sealing compound is applied. Whether the seal is made with Whiteheads' varnish or Norbecutane is probably immaterial.

Active and passive movement now begin and are assiduously practised by physiotherapist and patient. The hand is kept elevated as far as possible, but if swelling is always threatening a compression bandage is applied each night until it is obviously not necessary.

The need for rehabilitation is in inverse proportion to the patient's intelligence and is often, therefore, required. The surgeon should not sponsor long periods of rehabilitation. If a hand is stiffened by injury it may be pointless to look backwards. When surgery has done its best the patient should, if necessary, be taught a new job suitable to the capabilities of the new hand.

Lacerations with Skin Loss

If surface area is lost at the injury, or if skin is excised at primary surgery, the defect must be made good. It is not a good plan to allow a skin defect of the hand to heal by granulations. Granulation tissue will form on any surface which is denuded of skin. Granulation tissue is the bed in which fibrous tissue develops. Scar tissue cannot help but limit joint movement. To some extent granulation tissue can be restrained from exuberance by pressure.

Widespread injuries, such as degloving, which need immediate extensive resurfacing are not dealt with here. To remedy large skin defects is a difficult problem, deep in the ambit of plastic surgery. Remarks will be confined to the everyday closure of the small skin loss: a more frequent injury.

The surgeon will be faced with a problem of skin closure after he has carried out an inspection of the wound. The area may be increased by excision should this be necessary. Often the loss is trivial and suture can be obtained by undercutting the skin for a small distance on either side and advancing the edges. Tension is the main bugbear following suture

with skin loss. Tension is the factor above all that will spoil an otherwise good closure. It must be avoided. Tension deprives the skin edge of its abundant blood supply and, though it may not be enough to produce ischæmic necrosis, the skin edge may be unable to cope with minor contamination remaining after excision. To some extent skin tension can be reduced by scrupulous suture of deeper tissue by interrupted fine catgut stitches. If a deeper layer can be sutured it is usually an advantage to do so, because not only is tension relieved but dead space is obliterated. A dead space must be avoided, otherwise a hæmatoma will inevitably collect in spite of the best contour dressing or drainage.

It may be obvious to the surgeon that no skin advancement by undercutting will enable the wound to be closed. Sometimes a small flap can be swung through a few degrees or a form of Z-plasty can be used to cover a local defect. Skin salvaged from a mutilated finger condemned to ablation is a great asset. It may be of considerable area and with its usual blood supply it can be trimmed to size and spread over a skin defect on the front or back of the hand. These manœuvres will not be detailed because they do not have great practical application as first aid measures and they will not be undertaken by a surgeon without previous experience of this form of skin cover.

By far the most practical method of covering a skin defect which cannot be closed by simple advancement is by the use of a thin split skin graft. A split skin graft may be used either as a temporary or a permanent skin cover. The conception that a sheet of split skin can be used to replace tulle gras or dry gauze as a dressing is not new. As an idea it should be fostered. Even though it is obvious that not all the skin can survive, the bed being unsuitable, it should be used as a planned temporary dressing. Scar formation is instantly halted when the graft has been successfully applied (Fig. 19). The graft will only ‘ take ’ if it is firmly applied to a vascular bed. It is not applicable when the loss has exposed a tendon sheath, tendons or bone. In such instances the repair becomes a much more formidable procedure.

The Procedure. The denuded area is defined, and if large, a template of jaconet is made to help in fashioning the free graft. The edges are trimmed and bleeding is stopped by pressure and the occasional use of fine ligatures. A small trimming of bone may be necessary. Ordinarily, in relatively minor instances of this nature, the graft is obtained from the flexor aspect of the same forearm, which is especially appropriate if the surgery is being carried out under a brachial plexus block. The skin is prepared by washing with detergent and saline, and the skin graft is removed by a razor or Humby knife. The graft is applied to the denuded area and accurately trimmed to the edge so that it can be meticulously sutured. The best suture material in this case is very fine serum-proof silk on an atraumatic needle. A few stab holes in the graft allow drainage of serum. When the skin edges have been accurately apposed, a contour dressing, moistened with Cremor proflavine, is applied under some pres-

sure. The degree of pressure is impossible to describe. Too much pressure will prevent the graft from being vascularized and it will die. Too little pressure may permit a hæmatoma to form or serum to collect beneath. In this instance, also, the graft is sure to die. Only experience can guide the surgeon in assessing the correct degree of pressure to apply. Such a dressing is best left alone for four or five days, unless some indication demanding inspection develops previously. At this time the wound may be inspected but further pressure should be applied for several more days, until the stitches are removed. Then it will be appropriate to begin



Fig. 19 (*a*). This friction burn involved tendons



Fig. 19 (*b*). A split-skin cover was applied immediately as a dressing.

movement of the local joints to prevent stiffness from becoming irreversible. At a later date, perhaps weeks or months, it will be possible to assess the state of the hand. There may be entire skin cover or there may be several granulating spots. If the former, it will have to be decided whether the graft is satisfactory regarding tautness, thickness and durability. If undue tautness of the free graft is limiting movement, it should be replaced either by a dermatome graft or a pedicle graft of some sort. If the graft is thin, tendon motion beneath is apt to be obstructed and this is an additional reason for replacement of the temporary skin dressing, even if there are some unhealed spots present.

If the denuded area is unsuitable to accept a free graft because its base is avascular in parts, a full thickness pedunculated flap may be applied.

It is not too difficult to fashion a flap from the abdomen to cover any aspect of the hand (Fig. 20). Clearly it is a formidable procedure more easily stated in theory than carried out in practice. Extensive skin losses, on the back of the hand especially, are ideally resurfaced by an immediate direct flap if tendons are exposed.

To allow an area to granulate for a time before grafting is theoretically permissible if the granulations are removed and a living flap is applied. The disadvantage, however, is that the distal tissue, that is to say the fingers, becomes œdematous because of blockage to venous and lymphatic return. This induces finger stiffness and is to be avoided. If, therefore,



FIG 20 (*a*). This hand was covered by a direct flap two weeks after injury, during which time fractures of the radius and ulnar had been neutralized by plating.

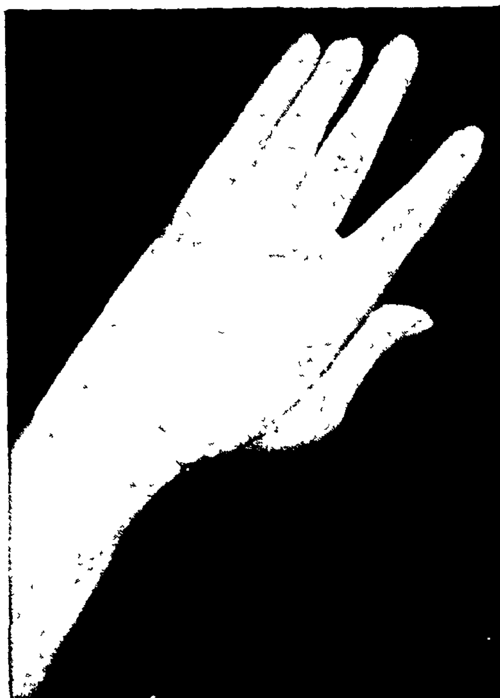


FIG. 20 (*b*) Good function and appearance resulted. (By courtesy of Mr. Richard Battle)

a skin defect cannot be made good by local resources the best all-purpose closure is obtained by free skin grafting. If the bed is unsuitable a direct flap should be applied. If the skill for this is not immediately available a pressure dressing of tulle gras will restrain granulation until the necessary skill in plastic surgery materializes.

Traumatic Amputation of the Finger Tip. This particular example of skin loss is dealt with separately, partly on account of the frequency of the injury and partly because, to a skilled man, the loss of this small area of skin may cause disability out of proportion to the damage inflicted. Because of the troublesome nature of the injury special methods of repair have been developed, with the idea of minimizing the disability as far as

possible. This is an injury of the machine shop rather than of the home. Skin loss at the tip of the finger is important in so far as the sensitive pad of skin is missing. If healing is permitted by granulations, the resulting scar is useless as a sense organ and is tender; moreover, it will not stand up to rough usage.

If the tip of the digit is all but amputated and is hanging by a thread of skin, the correct method of treatment is replacement (Fig. 21). If the flap is thick, containing tissue of the pulp of the finger, this should be pared off so that the graft consists of dermis alone. It is then reapplied and sutured carefully and closely around the edge. The nail will probably have been divided at some point. The proximal part is best left alone: in many respects the nail can be considered as a dressing.



FIG. 21 (*a*) The impulse to snip off the all but amputated finger tip was resisted.

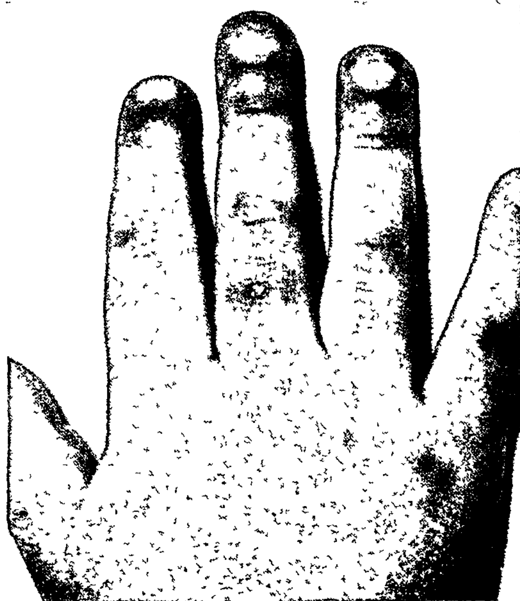


FIG 21 (*b*). With this reward.

If the traumatic amputation of the tip of the digit is complete, the tissue, if available, should be sutured back into place after suitable preparation and removal of attached fat. It is by no means certain that skin so replaced will survive, but frequently it does so in the most unpromising instances. If it does not survive, a hard, black crust is formed at the tip of the finger (Fig. 22). In such instances it seems that the deeper layers survive, forming islets of epithelialization, so that the scar is more malleable and sensitive than a scar formed purely by ingrowth from the edge. The replaced skin may float off the finger tip as a result of infection. Then it must be removed *in toto*.

In instances where the original skin is not available, or replacement is not appropriate or has been tried and failed, it may be necessary to cover the end of a finger tip by other means. A Thiersch graft is always a

possibility and is a most useful standby. It may be applied as a temporary dressing until reconstructive surgery can take place. McCash of Basingstoke has described a novel method of obtaining skin replacement for the tip of the finger. The skin of the tip of a toe is already moulded to a similar shape to that required. If only the tip of the finger is lost, it can be replaced by corresponding skin from a toe. Skin without fat is transferred and the tip segment of the toe is amputated to obtain closure. Often this temporary dressing turns out to be a permanent skin cover because it is so satisfactory.

Bone may be removed from the tip of the digit to effect a primary skin closure by apposition. This is the method of choice in individuals who do not need delicate control of the finger. It is a very practical method of



FIG 22 In this instance the tip of the medius was not viable

producing skin cover which is durable, satisfactory and sensitive. This method is considered as unenterprising and unsporting by the experts but if only one finger is involved, trimming back the phalanx and closing the wound by skin apposition is the best all-purpose treatment.

The method of finger-tip replacement by a thenar flap must be mentioned as it is now in vogue. It will be remembered that fingers in individual flexion all point to the thenar eminence. The mutilated finger is flexed to the thenar eminence and a flap is defined and raised in such a manner that its terminal part will lie in easy contact with the finger tip. A split skin graft is obtained from the forearm and sutured into the palmar defect and on to the deep aspect of the raised flap as far as that part to be in direct contact with the finger. The palmar flap is sutured to the finger tip after a rather tricky little dressing has been applied to the free graft to prevent its being floated off by serum. In three weeks the base of the

flap can be divided and any minor tidying up of the digit or palm can be carried out. Skin from the thenar eminence is very satisfactory on the



(a)



(c)



(b)

FIG 23. Loss of the tip of the ring finger was made good by a split-skin graft The long finger was restored by a thenar flap. Although the appearances differ the results are functionally similar

tip of the index finger. It rapidly regains sensation and it is durable (Fig. 23). Similar loss occurring to the tip of the thumb is not so easily dealt with, but it is possible to lift a flap from the radial border of the palm

which can be made to cover some traumatic defects of the thumb. If there is difficulty in the mechanical arrangement of such a flap, it is better that the thumb itself is covered by a split skin graft. Should this not be satisfactory as a permanent cover, replacement can be made by definitive plastic surgery at a later date.

Traumatic Amputations

There is, of course, no sharp division between the injury which can rightly be described as crushing and that which is better described as a traumatic amputation. The essential difference between the two is more



FIG. 24 (*a*). That which must be amputated is beyond recall.

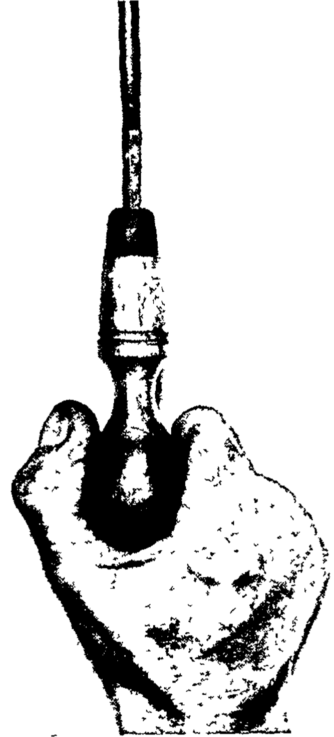


FIG. 24 (*b*) Mobility of the thumb against the stump of the index converts this hand from a paper-weight into a useful gripping tool.

likely to concern the treatment than the injury. Any crushing of a digit so severe that amputation is obviously necessary may rightly be described as a traumatic amputation.

The guiding principle of treatment of injuries of this sort is that the tissue which remains is more important than the tissue removed. That which is amputated is past praying for; that which remains must be cherished (Fig. 24). A traumatic amputation comes within the definition of severe injury, which means that full examination of the extent of the damage does not take place until the patient is anæsthetized, the hand prepared and an exsanguinating blood pressure cuff applied. At this time the nature of the injury can be defined and the treatment decided. In the first instance massive lumps of dead tissue are removed. Then all tissue

mutilated beyond hope of useful functional recovery is also removed. That which remains must be repaired and adequate skin cover must be sought and found. Judging whether a finger is mutilated beyond hope of reasonable function is difficult. Obviously a digit hanging solely by a tendon or a narrow bit of skin has got to be sacrificed because it will not survive. A single digit lacerated to a lesser degree, with skin loss and joints opened, would be better sacrificed because it will never be able to play its part with the other fingers. Being stiff it is in itself liable to hamper the usefulness of the other digits. Several similarly mutilated fingers would not be amputated. They would be preserved with care, so that together they may form some sort of functional unit which can be of assistance to the patient. Clearly, when in doubt, tissue must be preserved, because a definitive amputation at a later date can always be carried out after consultation with the patient who may know his requirements better than does the surgeon.

It should be remembered that even though a digit will have to be sacrificed eventually because it is useless, some of the skin may be of use in replacing skin loss on the remaining part of the hand or other fingers. The surgeon, therefore, must bear in mind at the time of primary surgery that good sensitive skin, covering a finger that will be stiff and useless, is to be preserved. The doomed skeleton within is retained as a temporary scaffold, to be sacrificed later if expedient. This decision, of course, must be made at the time of primary surgery.

In short, the principles guiding the surgeon at the time of first aid surgery are as follows: the tissue which is obviously dead, or clearly of no functional value, is to be sacrificed. If the injury to the hand is extensive, preserve all that is possible even though it may seem of no functional value. A bit of healthy, sensitive skin may be of more value if it is spread over a defect than in its normal situation. Finally, as much tissue of the thumb as possible should be preserved.

The technique of surgery is the same as that used for a repair of other injuries to the hand but it is more exacting and has to be carried out meticulously. Not only must tissue damaged in bulk be removed but it is probable that the skin edges will be contused so that they must be pared back a millimetre or so by means of fine, sharp scissors. When the damaged tissue has been removed the surgeon has to think of repair and he will have to bring the skin together as best he may, in an extemporary manner and in order to obtain the close apposition necessary for limited scarring. Small bits of otherwise normal skin which are of no use may have to be sacrificed. In this instance, as in others, hæmostasis must be complete and a dead space is to be avoided. This is guarded against by apposition of deep structures with fine catgut stitches and in almost all instances a small wick drain is useful.

Elective Amputations

The indications for an elective amputation of finger are elementary.

The fact that a finger is useless does not demand amputation. If, however, the finger is also a nuisance, especially if it is a danger in a machine shop, it should be sacrificed. Other indications include an unsightly appearance or troublesome pain. A useless finger is apt to hamper function of the other fingers and is better removed.

There are a few simple rules governing the site of digital amputations. The old division into functional and cosmetic amputations is purely arbitrary and of no practical value. The appearance of a hand is deter-



FIG. 25. The thumb was blown off by an explosion at work. The surgeon who offered to reconstruct a thumb was considered by the patient to be mad. The patient received £3,000 and special damages and continues to work at his pre-accident wage.

mined as much by the function as by the outline. It is dependent on that which remains rather more than on that which has been removed.

The principles as a basis of the practice, are elementary. They are these: first, no person can afford to spare a piece of thumb. Second, almost any person can spare a finger if those remaining are normal. Third, if more than one finger is damaged the maximum possible of each finger should be preserved. There are only minor variations in the application of these principles in practice.

The Thumb. The thumb is essential for any pinching action. Gibbons are able to grasp boughs of trees and dart about with electric agility: they have no thumb. The human locks the object to be grasped into the palm

with the thumb. If removal of some distal portion of the thumb is necessary because it is not viable the amputation is to be as limited as possible in spite of stiff proximal joints. After surgery the stump should be held in the opposed position by a splint or bandage. A thumb which has become stiff in the same plane as the fingers might as well have been ablated.

Elaborate campaigns in plastic surgery to reconstruct the thumb are in vogue. Pinching, to be effective, requires skin sensibility and joint-position sense together with delicate control. These attributes are rarely regained by elaborate building operations. In these days of generous compensation for injury patients will not consider reconstructive surgery



FIG. 26 This useless stump was amputated. The result is shown in Fig. 27 (*b*) and (*d*). Can there be any doubt but that reamputation was wise?

for loss of a thumb until the sum is awarded: then they have no need to (Fig. 25).

The Single Finger. The site of election of amputation of a finger is at the point where the finger becomes normal (Fig. 26). Amputation of any of the four fingers through the terminal interphalangeal joint leaves a useful digit if the proximal joints are mobile. This is a standard procedure for the crushed terminal phalanx and is applicable to all four fingers equally.

(*a*) *Either Marginal Finger.* The index and little fingers have to be considered separately from the other two.

If the lesion cannot be dealt with by amputation through the terminal joint, or at least the terminal part of the middle phalanx, the whole of the finger may just as well be removed. This implements the principle that any individual can afford to lose one finger. A surviving proximal

phalanx of the index or minimus makes no contribution to the usefulness of the hand. Amputation through the metacarpo-phalangeal joint, though theoretically desirable, leaves an unsightly lump at the margin

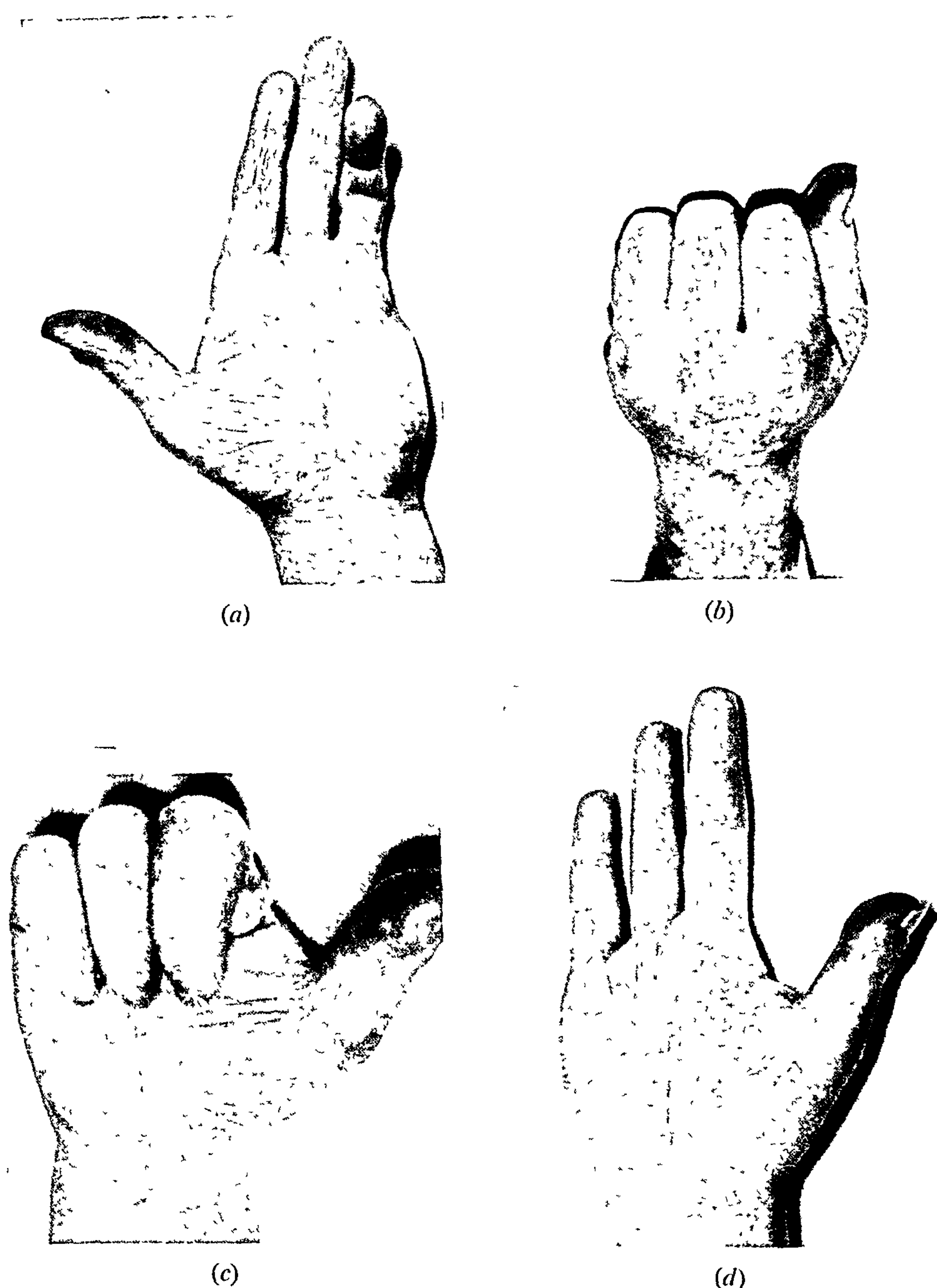


FIG. 27

(a) and (b). The hand is of reasonable appearance except for the hypothenar bulge
(c) and (d). The observer needs to be able to count up to five to detect abnormality.

of the palm. Removal of the metacarpal head by section through the shaft of the bone leaves a more attractive and normal appearance to the margin of the palm (Fig 27).

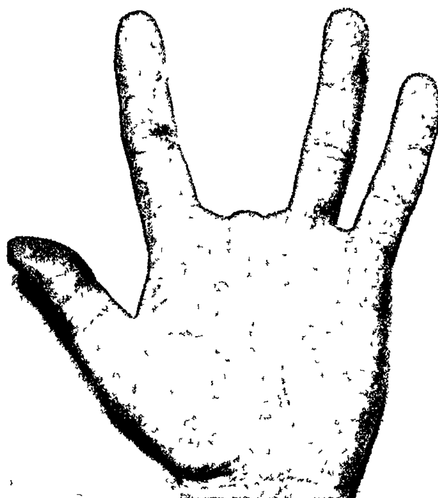
(*b*) *Either Central Finger.* This matter is a little more complex. If amputation proximal to the distal interphalangeal joint is necessary there are two alternative sites from which to choose. Disarticulation at the metacarpo-phalangeal joint is often undesirable because of the inevitable



(*a*)



(*b*)



(*c*)



(*d*)

FIG. 28.

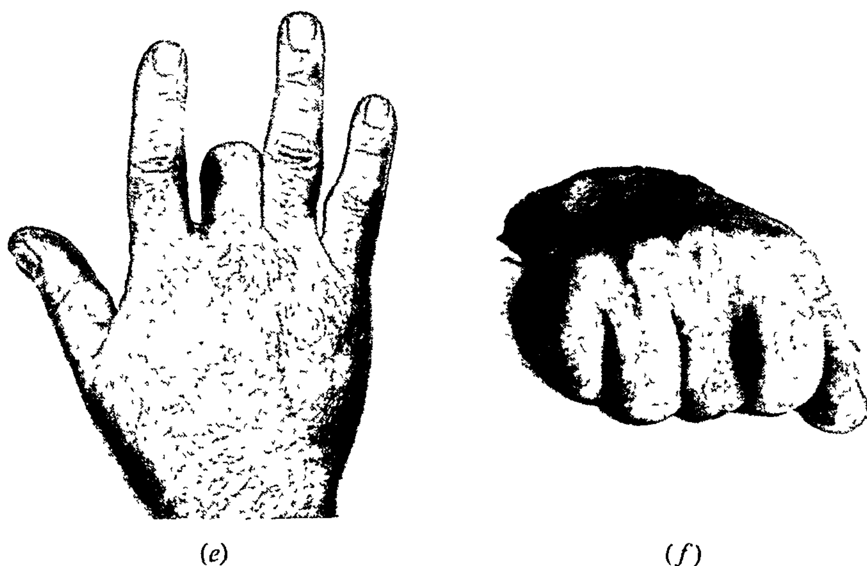
(*a*) and (*b*). Removal of the metacarpal head gives a reasonable appearance and the hand is a useful container.

(*c*) and (*d*) This hand is neither of elegant appearance nor of any use as a container.

gap which remains between adjacent digits. The hand can never be used to contain small objects either individually or *en masse*. The patient may have to move his small change into the opposite pocket. Moreover the gap is unsightly. Removal of the metacarpal head, however, allows some approximation of the digital rays to take place, making the hand

more useful as a container, and improving the appearance at rest (Fig. 28 a–d).

If the injury will permit, disarticulation through the proximal interphalangeal joint may be considered if the knuckle joint is fully mobile. Amputation at this level permits the hand to be used as a container and also gives a normal appearance in repose (Fig. 28 e and f). A choice of site of amputation is available in the two central fingers if the metacarpophalangeal joint is free and the proximal phalanx intact. The actual choice of site is determined individually by the surgeon in consultation with the patient.



(*e*) (*f*)

FIG. 28 (*continued*).

(*e*) and (*f*) This is an alternative to (*a*) and (*b*). The hand is a very good container and can look normal at rest

Multiple Digital Injuries. If several fingers are injured the policy is different. Something short of perfect function is to be anticipated. The maximum of hand function is more likely to be gained by careful positioning of the injured fingers than by amputation. Arthrodesis of proximal interphalangeal joints may well be performed on fingers that would be amputated if the injury was not multiple. One of several damaged fingers may be amputated for the sake of its skin covering. Cannibalism that sacrifices a useless finger may furnish good pedunculated skin cover for an adjacent finger hampered in movement by scarring. In general only the non-viable portion of a finger (in the case of multiple injuries) is amputated (Fig. 29). Should a given portion of finger turn out to be more of a hindrance than a help in spite of careful positioning, it is better that it should be removed without delay.

In some instances patients will prefer to retain a functionless digit if it can be given a reasonably normal appearance in the position of rest.

A society woman, who has a functionless digit as a result of a thecal whitlow, will rarely submit to amputation. She is much more likely to request assistance in getting the finger straighter, so that the appearance is natural with the hand at rest. Such a patient will be willing to put up with the inconvenience of a functionless finger for cosmetic vanity. This is not an unreasonable attitude. The surgeon knows perfectly well that he would be sufficiently deft at his surgery if both his index fingers were amputated. To get this simple fact accepted by an ignorant patient is probably more than should be expected.

Technique. Within the fingers amputation should, if possible, be a disarticulation at an interphalangeal joint. The technique is simple. A





FIG. 29 (*a*) and (*b*) In the case of multiple finger injuries the maximum of each finger is retained irrespective of theoretical sites of election for amputation

volar flap is used if possible. The flap is fashioned, lifted and thinned. If the palmar skin flap is left too thick, the remaining phalanx will seem to be too long. The alternative is to shorten the phalanx somewhat. The joint is disarticulated, preserving the articular cartilage. No special attention is paid to the tendons, vessels or nerves. If the vessels bleed exuberantly they are ligatured. When the skin has been sutured no drainage is necessary. Disarticulation of any of the metacarpo-phalangeal joints is rarely performed. the metacarpal head is usually removed with the digit. A racquet incision is made encircling the base of the finger and the handle is carried proximally on the dorsal aspect. The transverse metacarpal ligament is cut and the bone is divided by forceps. The point of section in the two outboard fingers is at the middle of the metacarpal

shaft, bevelled if appropriate, and in the two inboard fingers at the metacarpal neck.

It is thought by some that the most common individual antecedent factor in a painful digital neuroma syndrome is tightness of the skin flap. The pedestrian habit of cutting the flaps a good deal too long and trimming them with scissors at the moment of suture, will seem unsporting to some, but this technique may prevent the trouble of a painful neuroma. It is a fact that the treatment of the skin is more closely related to a painful neuroma than the treatment of the digital nerve. The digital nerves, therefore, are divided where they are found and the tourniquet is released before suture of the wound so that the digital arteries can be identified and ligatured with fine catgut. A dead space is apt to form, even after a well planned racquet incision, and for this reason it is wise to drain the wound for forty-eight hours by means of a wick emerging from the proximal part of the dorsal wound.

CHAPTER 4

INFECTIONS OF THE HAND

THE pattern of the infections of the hand has undergone a great change since the introduction of antibiotics. In civilized countries, at any rate, the number of grotesquely swollen hands with burrowing and grave infection is very small compared with previously. In the days before antibiotics, ignorance or neglect could create so extensive a suppuration from a simple prick or laceration that not only was function of the hand destroyed but the life of the patient might also be lost. In these days ignorance and neglect do not reap so fearful a reward. Even when an infection is firmly established, antibiotics will at least save life and usually restore a greater degree of function than would be expected.

It is not at all certain that the surgical aspects remain the same as they were. Previously, surgical treatment consisted in liberating pus, at the correct time, by incision. Difficulty arose in determining the site of the inflammation and deciding when pus had formed. Furthermore, surgery was not able to assist unless the inflammation was sufficiently localized to form pus. In spreading infections caused by streptococcus hæmolyticus there was often no opportunity for incision.

Antibiotic therapy, begun by the sulphonamides and continued by penicillin and its descendants, has brought about a change. Lives are no longer lost nor limbs amputated. But antibiotics have not replaced the knife. Doubtless, if inflammation could be treated early enough resolution would be frequent. Usually, however, patients do not report within two or three days of onset of the infection, by which time necrosis and pus formation, that is to say localization, may be established. In such an instance penicillin is not necessary to prevent spread; nor will incision be avoided. Spreading infections with lymphangitis, usually streptococcal, or infections in dangerous sites, such as the tendon sheaths or palmar spaces, need penicillin because of their potential gravity. Penicillin has made treatment more simple and more safe but its use has reduced the frequency of poulticing more than the need for incision. A discharging sinus of longer or shorter duration is bound to follow incision and this can be irksome to the patient as well as time consuming.

At this time we are in a transitional phase in relation to the treatment of suppuration. Previously, surgery presumed to do no more than assist nature to localize inflammation and later to liberate pus by incision. By the aid of antibiotics surgery has advanced from a subordinate role to take the lead by treating inflammation by extirpation. That is to say, localized inflammation is cut out.

Scott of Oxford and others have reported a most interesting technique using these new principles in the treatment of hand suppuration. That

is to say, suppuration is treated by extirpation after localization has been induced by antibiotics. The object is to obtain primary healing. Briefly the method is as follows. When the inflammation is localized, it is exposed through a suitably placed but conventional incision. This will often involve raising a considerable skin flap. Under a tourniquet it is possible to recognize the central necrosis, surrounded by an area of tension and œdema. The whole is excised, whereby the inflammatory zone is removed, leaving only the peripheral reactionary hyperæmia. The skin is replaced and sutured and the part is immobilized with a plaster splint. About half a million units of soluble penicillin are prescribed in two daily doses for five days. Antibiotics, of course, are an essential of treatment.

If the infection should be discharging the skin incision is planned to include the sinus, which is removed with the seat of inflammation. Occasionally a skin graft is necessary to close the defect but its application is delayed for some days.

The originators of this system claim that this method reduces the healing time by half and consequently the temporary disability due to joint stiffness is much reduced in time. To obtain controlled primary healing in place of a sinus discharging for an indefinite, though not for necessarily a long, time is a considerable advance in treatment. Probably this method of extirpation of inflammatory sites is here to stay but the older methods of treatment are in the main referred to and they should not yet be forgotten. To-day one may classify the greater proportion of hand and finger infections as trivial. In countries where the use of penicillin, or its associates, is not universal at the first signs of infection, the fully developed types of hand infection are sometimes to be seen.

The Pricked Finger

This frequent injury occurs universally in all people. Clearly it can be the starting point of a pulp infection. In the case of a simple prick by a nail or a needle it is unnecessary to treat the matter seriously in the first instance. If a virulent infection has been introduced, this will become evident at the end of twelve hours. If the infection is of milder nature the delay before symptoms develop will be longer. When, therefore, a prick occurs in the home or factory, the finger may be washed and a protective dressing applied; but there is no occasion to inject penicillin unless or until signs of inflammation develop. If inflammation develops, the patient should be given a million units of penicillin immediately and half a million twice a day for three days. Usually by then the inflammation has resolved. A casual injection of penicillin in the doctor's surgery following an alleged pricked finger will only cloud the issue. If penicillin does not control the infection the antibiotic must be changed. If the organism is penicillin-resistant, it is wise to resort to achromycin or erythromycin immediately. If pus is formed it must be typed against the various antibiotics so that the correct one can be given. Sometimes the pus will be sterile.

Not so long ago instances of death following a pricked finger in the course of a surgical operation or autopsy were by no means rare. In twelve hours, although the original prick could not be located, there could be lymphangitis extending up the arm. This was the curtain-raiser to septicæmia. Death followed in spite of amputation of the arm. In these days, however, we have no fears provided effective antibiotic therapy is used.

Pulp Infection

The Terminal Pulp. This follows direct implantation of infection into



FIG. 30. Heat must be used with intelligence. In this instance the patient used a lot of heat and no intelligence

Tissue devitalized by infection was killed by hot water used too often and too hot

the fibro-fatty tissue deep to the dermis. Most often the region of the terminal phalanx is affected but pulp infection may equally well develop over the volar aspect of the middle or proximal phalanx. The tissue of the palmar surface of the finger is peculiar in that there are vertical fibrous septa which connect and fix the dermis to the underlying phalanx or fibrous tendon sheath. Within the spaces created by these trabeculæ of fibrous tissue there is sensitive fatty tissue which makes up the bulk of the pulp.

In the case of a terminal infection the tension which develops within the pulp is extreme because of the tight fixation of the dermis to the bone which prevents swelling. The terminal interphalangeal crease limits

spread of the infection proximally. Sometimes the tension which develops is so great that the phalanx itself necroses, presumably due to thrombosis of its blood supply. It is rare for an infection of the terminal pulp, wherever located, to spread into the tendon sheath.

Local application of heat assists by aiding the normal physiological hyperæmia and it is also soothing to the patient (Fig. 30). When pus is present there is no alternative to incision. It is not always easy to be sure that pus is present: a good deal of experience is necessary. Swelling and tenderness alone are not enough to denote pus. Liberation of pus may be carried out by one of two methods. A horseshoe incision around the end of the finger, parallel with the nail, will open the pulp sufficiently to ensure adequate and complete drainage. In certain instances, however, because of the patient's work, it may be inappropriate to make a horseshoe incision. If delicate use of the terminal pulp is especially desirable, two lateral incisions, one on each side of the tip of the finger, can be used. The incisions should communicate and there should be through drainage by means of a fine rubber dam for forty-eight hours. It is insufficient merely to make two lateral incisions. The pulp tissue seems to have an embarrassing faculty for prompt healing so that sometimes the pulp has to be reopened.

If the incision is delayed for too long the tension which develops may be great enough to cause necrosis and sequestration of the terminal phalanx. In such an instance healing is not prompt and it is likely that some at least of the terminal phalanx will have to be removed before healing will take place. A horseshoe incision, which converts the palmar aspect of the pulp into a flap, is turned back, the phalanx is exposed and the necrotic bone is scraped away. The flap is laid back unstitched and if all the necrotic bone has been removed healing will be prompt. If much of the phalanx is removed or exfoliates itself, the end of the finger will always remain withered. This is unsightly in a woman.

The Middle Pulp. In this instance, also, infection follows direct implantation. A piece of wire wool in the washing-up sink may easily penetrate the skin and carry infection into the pulp, which, if it develops, will cause great tension and disturbance because the creases on either side of the middle phalanx prevent the extension of pus distally or proximally. The symptoms are similar to those for a pulp infection of the tip of the finger. Local, hard and brawny swelling, with exquisite tenderness on pressure and throbbing pain at rest, is present varying in degree with the virulence and extent of the inflammation. Occasionally infection in this site is able to enter the digital sheath as a direct extension and cause the dread misery of tendon sheath infection. If the surgeon delays sufficiently long to allow a middle pulp infection to enter the digital sheath he will have great difficulty in preventing death of the tendons. In such a case the result of a simple prick of the finger over the middle phalanx is a stiff, useless digit which would be better amputated.

The potentialities of a mild pulp infection are obvious. All must be

treated seriously. If the infection is pointing, suggesting that the abscess is superficial, it is better to incise it locally. If the surgeon believes that pus is present, though not pointing directly, a formal lateral incision should be made. Frequently the patient does not report for treatment until pus is present. If the inflammation is extensive it may be necessary to make two lateral incisions, in which case a through and through drain must be used for forty-eight hours, otherwise premature healing will occur. Ordinarily, when the drain is removed, healing rapidly progresses and no tenderness remains after a few days. If tenderness remains after three days, and especially if the finger is flexed, it is probable that the sheath has become infected. Sheath involvement should be suspected if at any time the base of the finger becomes tender. This complication still happens occasionally, provoked by neglect or delay.

Proximal Digital and Distal Palmar Pulp. If the original injury occurs over the proximal phalanx, pus may form at the base of the finger. The local signs will be similar to those of a pulp infection elsewhere. A good deal of swelling and brawny induration, together with local tenderness of extreme degree, will be present. If the pus is pointing, incision should not be delayed because in this situation the possibilities of spread are greater and more formidable than elsewhere. Although it is not possible for the pus to spread distally, extension into the palm readily occurs deep to the palmar fascia. Less frequently pus may also spread up the lumbrical canal into the mid-palmar space. Rarely it may track dorsally in the finger and spread proximally on to the dorsum of the hand. There the swelling will be confused with the dorsal œdema which collects in the case of a palmar space infection. For all these reasons, therefore, it is necessary to recognize the existence of pus as soon as it is formed, and to liberate it.

A local collection of pus pointing in the proximal pulp should be opened by one local incision, or two on opposite aspects of the finger connecting them by a drain for forty-eight hours. If there is evidence that the pus has tracked proximally, the incision should be continued into the distal part of the palm as far as the transverse crease. If the mid-palmar space is infected it should be opened by passing artery forceps along the line of the lumbrical muscle. If pus is present it will be liberated by this means without further incision. Direct extension of infection into the tendon sheath rarely occurs as a result of proximal pulp or distal palmar infection. The fibrous, tendinous sheath is extremely tough over the proximal phalanx, whereas over the middle phalanx the sheath is of a lighter texture, permitting easier extension of a pulp infection into the digital theca.

The Subcuticular Whitlow

This particular type of infection is important only in so far as it is likely to be neglected. The apparent innocence of a septic blister on the palmar part of the hand may mask a deeper collection of pus that is

beginning to burrow and spread. This collar stud abscess may be overlooked unless it is anticipated (Fig. 31).

There may or may not be a history of local implantation. There are local signs of inflammation and soon the epidermis is lifted by a collection of pus. When this is clipped away and swabbed clean a small hole through the dermis may be seen, through which pus is oozing from a deeper collection. If, in fact, the apparently innocent subcuticular whitlow is in reality a collar stud abscess, it must be treated appropriately. Under a general anæsthetic the obstructing isthmus of dermis has to be removed. A circular area of skin is removed around the communication



FIG 31 The pus is exuding from the depths of a ' collar stud ' abscess.

and the deep compartment is fully opened. The fairly extensive skin defect is covered with tulle gras, and, of course, the patient receives soluble penicillin.

The collar stud abscess lends itself to extirpation and immediate skin closure if there is sufficient skin cover available.

Paronychia

This is the most common type of infection of the finger. It is caused in a variety of ways. A splinter may be run underneath the nail; or the cuticle round the nail may be damaged; or sometimes the use of a stiff nailbrush will abrade the surroundings of the nail initiating an infection. The word paronychia implies not only infection around the nail but also

under it. In the first instance pain, swelling and redness will develop in the tissue at the side of the nail. Later, despite assiduous bathing of the finger, the infection is likely to advance round the base of the nail and may even spread to the other side. During this development the patient is usually able to liberate a small amount of pus by local tinkering. Household measures are rarely sufficient to cope with this condition. A paronychia in which the whole circumference of the nail is involved can only be treated by surgery. Pus beneath the nail is detected clinically by



FIG 32 (*a*). Paronychia with inflammation around the nail base.



FIG 32 (*b*) Simple removal of nail without incision over nail bed proved sufficient in this instance.

pressure on the nail. Pressure causes exquisite pain if pus is present. The nail must be removed without delay (Fig. 32).

Temporizing will not assist: it is correct to remove the nail under general anæsthesia. It is wise to incise on either side of the nail bed for a ¼ inch proximally, so that a dorsal flap can be lifted up. The whole nail bed is exposed and the flap can be kept raised by one layer of 'Vaseline' gauze. The finger is bandaged and if next day it is comfortable it is left alone, but on the second day the bandage is removed. The 'Vaseline' gauze will not require replacement and healing can be allowed to begin. From about the sixth or seventh day it is good to treat the nail bed with infra-red rays in order to heat it and dry it. At the same time talcum powder is applied until at last it becomes quite dry and epithelialized. At

this stage the nail bed is insensitive. The new nail may take four to six months to grow.

Sometimes if there is pus beneath the distal part of the nail only it is occasionally possible to remove the infection by cutting a deep V from the terminal part. The occasions suitable for this are not frequent. It is never worth while preserving half of the nail.

Dorsal Carbuncle

The back of the hand seems to be prone to infection or septic necrosis of the carbuncle type, particularly, of course, on the hair-bearing area.



FIG 33. The dorsal carbuncle may be on a finger as well as the dorsum of the hand.

The dorsal carbuncle, therefore, is frequent over the proximal phalangeal and the ulnar part of the dorsum of the hand. Its origin may be unrecognized or a carbuncle may follow a local prick, abrasion or graze, which is trivial in degree. The staphylococcus is responsible. In twelve hours or so the area becomes irritable, swollen, red and hard. The inflammation evolves until there is an indurated knob with a necrotic centre. Fluctuation is not present. The area consists of massive necrosis of the dermis and underlying fatty tissue, with a circumferential area of acute inflammation (Fig. 33).

In the first instance, while the carbuncle is developing, local treatment by glycerine and magnesium sulphate paste is as good now as ever it was.

At the same time the patient should have injections of aqueous penicillin, one million units daily. In spite of this, however, the carbuncle may mature and increase in size, in which case surgery will be necessary. A cruciate incision is made, centred in the middle of the carbuncle, and the flaps of skin thus formed are elevated. This permits drainage of the necrotic centre. The skin, which at the time of surgery may look dusky, thrombosed and precariously alive, will probably survive The transverse cruciate incisions should extend throughout the whole width of the inflammatory area. It is advisable to place a wick of ' Vaseline ' gauze in the central necrotic part, otherwise premature healing may spoil the

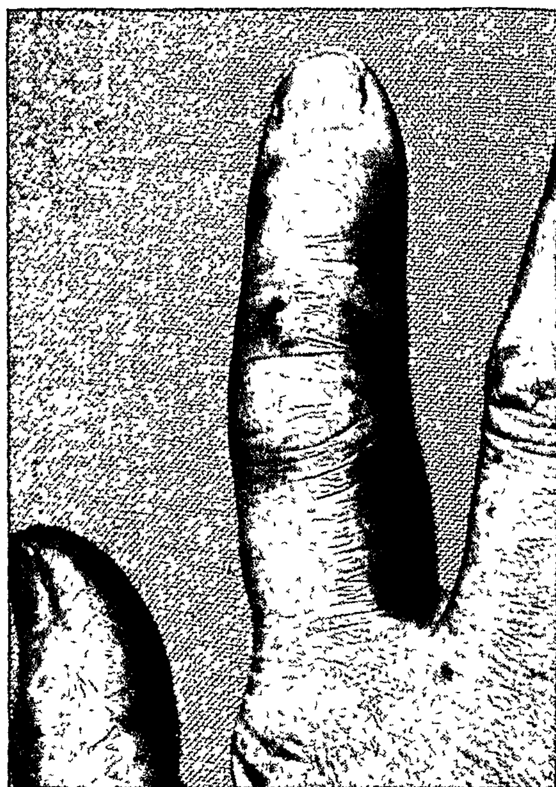


FIG 34 The erysipeloid may affect a finger, more often it is the dorsum of the hand A colour print is necessary to convey its characteristic appearance.

result. Sometimes the dermal infections on the back of the hand are of milder degree than the carbuncle and are resolved by penicillin and local heat applications.

The carbuncle lends itself especially to treatment by excision. The local septic necrosis can be removed and the remaining septic contamination suppressed by penicillin. The only difficulty is the skin A block excision of the infection may need a skin graft at a later date to repair the defect. It is not easy to assess the viability of the skin. The likelihood is that too much will be excised. The surgeon should err towards conservatism in skin removal. This method reduces the length of disability by the time that would be taken for the necrosis to slough itself away.

The Erysipeloid

This is a peculiar and specific condition which is frequent amongst workers who handle fish or meat, both in packing factories and slaughter houses. The infection is due to the entrance of a specific fungus through a trivial crack in the skin. This fungus is universal throughout the animal kingdom.

The erysipeloid seems only to occur on the back of the hand and fingers. The fact that the patient works with fish or poultry or shellfish is an assistance in the diagnosis. A local swelling develops which is discoloured and irritable. For three or four days the area increases in size. There is induration within the skin, stiffness of the surrounding joints due to loss of elasticity of the skin and a bluish discoloration, perhaps with blebs. The edge of the area is clear cut and without noticeable subcutaneous œdema. The condition itches considerably; it never suppurates and it never looks as if it will require incision. It was once called erythema migrans. In the ordinary course of events, without antibiotic treatment, erysipeloid spontaneously recedes well within three weeks. It is, therefore, self-limiting (Fig. 34).

No local treatment is necessary. Protection by a bandage is not essential unless the skin is broken. The patient is given daily injections of a million units of penicillin and the patient is nearly always cured within six days. Surgery is not necessary, even in neglected cases.

Tendon Sheath Infections

A tendon sheath infection, if uncontrolled by surgery or antibiotics, will lead to crippling loss of function. At best the tendons become adherent in their sheaths but more usually they slough. The finger is put beyond the possibility of functional recovery. It will be flexed and immobile. In fact it becomes a useless appendage.

(*a*) **Of the Index, Middle or Ring Fingers.** The anatomy of these three synovial sheaths in the fingers is similar in that they are self-contained and communicate neither with each other nor with the palmar synovial space. They lie within the fibrous sheath of the finger, extending into the palm for two fingers breadth. The source of infection of these tendon sheaths may be twofold. The sheath may be punctured by a penetrating injury at any point in its course. The injury varies from a simple puncture, as by a rose thorn or the tip of a file, to a laceration which obviously opens the tendon sheath. The other source of infection is by direct spread from mid-finger pulp infection. Longitudinal spread of pulp infections in the finger is restricted by the transverse creases. In the case of the middle section of the finger direct extension is possible into the synovial sheath because at the level of the proximal interphalangeal joint the fibrous sheath is partially deficient. Direct spread is possible and does happen, in spite of incision of the whitlow and the use of antibiotics. Early diagnosis is probably more important in this instance than in infection of any other compartment of the hand. The synovial sheath is surrounded throughout

the whole of its course by the fibrous sheath. Therefore infection, as soon as it develops, is liable to generate a great deal of local pressure which will ensure early and total necrosis of the tendons within the sheath (Fig. 35).

The diagnosis is fairly obvious; the whole of the finger is symmetrically swollen throughout its length on both aspects. The finger is held partially flexed and totally immobile. All voluntary action is suppressed and passive extension of the finger causes exquisite pain. There is tenderness on palpation throughout the volar surface of the finger and on the corre-

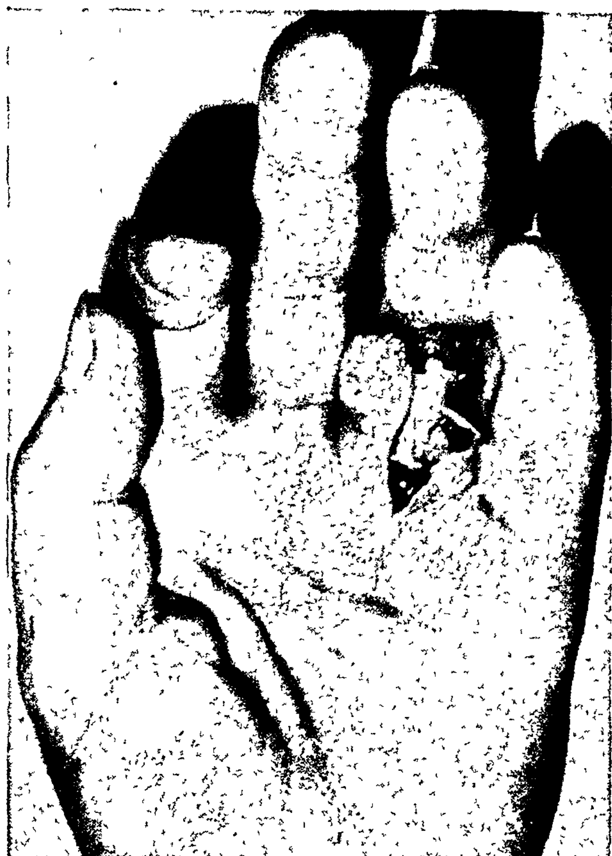


FIG. 35 The tendon sheath became infected as a result of a deep puncture with a needle The sloughing tendons are evident. they were excised.

sponding part of the distal aspect of the palm. If the infection has spread into the lumbrical canal there will be fullness in the cleft, with swelling and tenderness on the dorsum of the knuckles. Lumbrical involvement from the index finger is always on the radial side but spread from the long or ring fingers may occur on either side of the fingers, due to the anatomy of the lumbrical origins (Fig. 35).

Treatment by antibiotics will be started directly the initiating pulp infection is recognized. If the sheath infection is due to direct implantation, the severity of the wound or the deepness of the puncture will almost certainly provoke prophylactic injections of penicillin. When it is certain that a tendon sheath is infected, incision to relieve tension is instantly

necessary. Under a general anæsthetic a lateral incision is made throughout the length of the finger, avoiding the digital nerve and artery. This is easier said than done. Many surgeons prefer the assistance of the relatively bloodless field obtained by a blown-up blood pressure cuff applied at the wrist. It is wise to make the incision on the radial side of the finger, so that by simple elongation the lumbrical canal can be opened to liberate pus if present. The incision must curve as it sweeps into the palm, following the normal creases as far as possible.

If the incision is made early in the evolution of the infection the tendon sheath will be filled with opalascent synovial fluid. The use of a tourniquet will be an advantage in recognition of small amounts of fluid that can instantly be seen and cultured. The fluid will become more obviously purulent as time passes. In either instance the tendon will be dull in appearance and yellowish in colour. If incision is made before the endothelium surrounding the tendon is killed, it is possible that gliding will be restored if drainage is adequate and if the infection resolves rapidly. If it is decided that the tendons are necrotic they will have to be removed. It is just as well to remove all tendon that is available. If infection has already spread along the lumbrical canal the tendon may be divided at the proximal end of the wound. If the palm is not infected the tendons should be removed without pulling on them, otherwise they will retract and carry infection proximally.

(*b*) **Of the Little Finger and the Ulnar Bursa.** The distinction between the little finger and the other fingers in the matter of digital sheath infection is that inflammation of the little finger is enabled to spread proximally because of the normal communication between the sheath and the ulnar bursa. Intense pressure does not develop in the little finger following infection in the tendon sheath because the pus, as it is formed, is liberated into the ulnar bursa. The bursa is, in fact, a true synovial sheath extending proximally along the course of the tendons of the little finger. In the proximal part of the palm the sheath is enlarged to enclose all the flexor tendons of the fingers with the exception of the flexor longus pollicis. The reason for the continuity of the synovial sheath along the tendons of the fifth finger is that the attachment of the lumbrical to the profundus tendon of the fifth finger is not extensive, so that the synovial sheath is continuous along both tendons on the ulnar side. The source of infection of the fifth finger sheath and the ulnar bursa is similar to that of the other fingers.

The detection of infection of the tendon sheath of the fifth finger is similar to that for the others. The symmetrical swelling, the immobility of the minimus in the partially flexed position, together with exquisite tenderness on pressure and pain on attempted extension, leave the surgeon in no doubt. If the infection has tracked proximally into the main synovial sheath of all the tendons, that is to say the ulnar bursa, the diagnostic features alter. Infection of the ulnar bursa is an extensive affair. The hypothenar eminence becomes tense, swollen and humped up,

apparently deepening the palm. There is fullness at the base of the palm and sometimes above the anterior carpal ligament. All the fingers become immobilized and extremely painful if passively extended. There is tenderness along the course of the fifth finger tendons, especially, it is said, at the level of the proximal palmar crease.

Antibiotics must be continued. When pus is present the matter must be treated with energy and an incision is to be made extending the full length of the ulnar bursa. The finger is opened longitudinally along its ulnar border and the incision is continued proximally along the ulnar border of the hand so that the tendon can be exposed to the level of the pisiform bone. If the ulnar bursa has been infected for forty-eight hours or more, the incision should be continued proximally through the carpal ligament into the lower part of the forearm. The classical incision to expose the ulnar bursa courses through the palm, along the radial margin of the hypothenar eminence. The exposure obtained through this incision is excellent, though the appearance is appalling, and the scar along the palm is apt to be troublesome afterwards by becoming keloid.

The palmar part of the ulnar bursa may be exposed by another method. If the digital incision on the ulnar aspect of the finger is continued along the fifth metacarpal bone, the opponens minimi digiti and the hypothenar muscles can be lifted exposing the tendons of the fifth finger, surrounded by the synovial sheath. The incision can be extended proximally by lifting the pisiform bone with the flexor carpi ulnaris. The deep branch of the ulnar nerve is an embarrassment as it crosses the wound but it can be avoided. According to Henry the whole length of the ulnar bursa can be exposed by means of this incision, which is placed in a trouble-free aspect of the limb.

Antibiotics greatly modify the course of infection of this nature. Occasionally a neglected case will be met with; or for some reason antibiotics may fail to have the accustomed and expected control of the infection. Surgical principles must still be appreciated, though the technique will rarely have to be put to full use.

(*c*) **Of the Thumb and Radial Bursa.** In normal anatomy, the flexor longus pollicis tendon has a separate synovial sheath extending from its insertion to the musculo-tendinous junction above the wrist. There is an outer, tough fibrous sheath in the region of the insertion of the thenar muscles, extending for about an inch to restrain the tendon at the meta-carpo-phalangeal joint, distally the fibrous sheath is thin.

Usually the radial bursa is infected by a deep penetration in the pulp of the thumb over the proximal phalanx, or by a laceration in the same area. The other source of infection is by direct spread from an infected ulnar bursa. A penetration in the thenar eminence, by a chisel for instance, may not lead immediately to evident inflammation. There may be a latent period of three or four days, during which time the infection is spreading throughout the length of the bursa with little sign of suppuration.

The early diagnosis is not easy. The injury, or the site of the injury, may be visible, which will assist in assessing the possibilities of infection. The thumb will be symmetrically swollen in its phalangeal part and completely immobile, whereas the other fingers will move freely. Deep palpation over the thenar eminence will be very painful. It is unlikely that a firm diagnosis will be made until the whole length of the radial bursa has been involved causing tenderness above the carpal ligament and often swelling as well. The palm is not swollen unless the infection has been present for several days, by which time infection will almost certainly have spread into the ulnar bursa, leading to a full-scale, massive tenosynovitis suppurans.

Spread of infection from the radial to the ulnar bursa, and *vice versa*, is liable to occur in all instances of infection. The factors controlling spread are more likely to be the virulence and duration of infection, rather than the anatomical connection. Involvement of both bursæ by a compound palmar ganglion is extremely rare; this would not be so if anatomical communication were as frequent as instances of cross-infection would seem to indicate.

The patient will doubtless be given penicillin at the first tentative possibility of a radial bursa infection. When the diagnosis is sure, immediate relief of tension must be undertaken to prevent spread of the infection or necrosis of the tendon. It should, however, be said that necrosis of tendon from pressure is not so liable to occur in this instance as in the case of the digital sheath infections. Inflammation is able to spread into the capacious spaces of the forearm and so great tension does not build up so early or so much.

An incision is made along the radial border of the thumb, from the distal phalanx to the level of the metacarpo-phalangeal joint. The fibrous sheath at this level must be divided. It is almost always necessary to prolong the incision to ensure adequate drainage. The incision should be continued proximally toward the wrist, along the radial border of the metacarpal, lifting the opponens pollicis from the bone. The digital nerves to the thumb are not seen as they lie medial to the incision; they cannot be damaged. The skin incision passes proximally to the tuberosity of the scaphoid. At this point it crosses the wrist creases and can be continued longitudinally. The origin of the thenar muscles can be detached from the flexor retenaculum and the ridge on the trapezium. When this is done the whole course of the flexor longus pollicis tendon is exposed without damage and through a well-placed skin incision.

It is likely after a septic radial bursitis that flexor longus pollicis function will be impaired. If the tendon does not slough it will become adherent. The disability of the thumb, therefore, will be considerably increased if the motor branch to the median nerve is also divided by mistake. In such a case the thumb will be virtually useless. The traditional incision along the ulnar border of the thumb and across the thenar eminence often led to this catastrophe.

The long incision is by no means always necessary in instances of radial bursa infections. Although the tendon may be doomed, this can be recognized in the distal part of the wound. If this be so, it is better to divide the tendon at its insertion and pull it out of the hand through a fairly large incision at the lower part of the forearm. Drainage at either end of the tunnel will probably be adequate to reduce inflammation and the tedious separation of the sloughing tendon is anticipated. Once the tension is relieved and the infection mastered by the correct antibiotic, healing will take place in the matter of a few days.

Infection of the Palmar Spaces

Once again the anatomy should be recalled. Until invaded by inflammation the palmar spaces exist in name only and they are situated deep to the long flexor tendons. They are two in number: the thenar or adductor space, and the mid-palmar space. The mid-palmar space is the more important; it lies deep to the synovial sheaths of the tendons of the fifth, fourth and third fingers. The ulnar boundary of the space is the origin of the opponens minimi digiti muscle from the fifth metacarpal and on the radial side it is limited at the third metacarpal shaft where the transverse head of the thumb adductor has its origin. From this point a vertical, fibrous curtain leaves the third metacarpal and passes superficially to become lost in the fibro-fatty tissue lying on the radial aspect of the tendon of the middle finger. It is continuous with a deep prolongation of the palmar fascia.

The thenar space is less important. It lies at the same level as the mid-palmar space but to its radial side. It is superficial to the adductor muscles of the thumb and deep to the tendons to the index finger. To the radial side, the palmar fascia in the first interdigital cleft is the boundary.

Mid-Palmar Space. The two palmar spaces do not often naturally communicate but inflammation developing in one space will sometimes invade the other. Sources of infection of the mid-palmar space are varied. The tendon sheaths of the fifth, fourth and third fingers may overspill infection by way of the lumbrical canals. A mid-palmar space infection is usually a terminal involvement of any distal subcutaneous inflammation or tendon sheath infection that tracks along the lumbrical canals. Infection by direct implantation is rare.

The possibility of spreading infection into the mid-palmar space is borne in mind while the original inflammation is being treated. During the course of treatment for a boil on the back of the finger or palmar whitlow, or a tendon sheath infection, the patient will receive the necessary surgical treatment and also antibiotic therapy. Occasionally a neglected case may be found in which it is noticed on first examination that a palmar space infection is present. In any septic tendon sheath infection, a careful watch is kept on the state and shape of the palm.

In mid-palmar space infections the normal palmar concavity becomes

obliterated by swelling and sometimes it actually becomes convex (Fig. 36). Further, at this time the œdema of the dorsum of the hand will be very large. The dorsal swelling can be accepted as œdema alone and not as a collection of pus if it is painless on pressure. The hand sometimes becomes enormous. At the first appearance of swelling in the distal part of the palm, or in the region of the web, or increasing stiffness of other fingers beyond that which is reasonable, a mid-palmar space infection should be suspected.

In such a case the web, or webs, must be opened by an incision so that an artery forceps passed along the lumbrical canal and made to enter the



FIG 36 (*a*) Mid palmar space infection. The palm is convex and the fingers are choked and immobile



FIG 36 (*b*) The surgeon must restrain an impulse to incise the dorsum of the hand.

blown-up space permits free escape of pus. Where the infection of a palmar space is more intense or of longer standing the space must be opened by a different route. Henry has described another means of getting into the mid-palmar space from the ulnar aspect of the hand, by lifting up the hypothenar muscles from the fifth metacarpal, elevating the ulnar bursa and opening the palmar space from that aspect (see p. 162). In either event drainage of the space must be full and free, because the possibility of extending the infection into the adductor space is always present while inflammation lasts. If there is doubt about the thenar space it is worth while passing an instrument across the palm, deep to the flexor tendons, through the curtain and superficial to the adductor

muscles of the thumb to emerge through the skin on the radial aspect of the second metacarpal, between the tendons to the index fingers and the first dorsal interosseous muscle. If this passage is kept open by a rubber drain across the hand for forty-eight hours, premature healing and incomplete resolution will be prevented.

The Thenar or Adductor Space. Infection of the thenar space is not so frequent as that of the mid-palmar space, nor is it so dramatic or dangerous. The sources of infection consist of the tendon sheath of the index finger or the subcutaneous spaces of the proximal phalanx. In the latter case infection passes up the canal of the index lumbrical muscle. The space may be infected as a direct extension from virulent inflammation in the mid-palmar space. It is to be noted that the radial bursa does not communicate with the thenar space.

In nearly every instance there will be a source of infection in the hand which may or may not have been treated. If it has been treated the thenar space infection is merely an extension of the inflammation already recognized. The patient no doubt would have had adequate surgery for the curtain-raising infection and also be receiving antibiotic therapy. In a neglected instance, however, the thenar space infection will merely be an item in an inventory of very severe hand infection.

The diagnosis is not always easy: the thenar eminence seems blown up and tight, woody and indurated, but there is no convincing sign of fluctuation. The contour of the palm is never convex, though some swelling, particularly on the radial side, may be obvious on inspection and palpation. The thumb is held abducted and is motionless. The index finger may be completely immobile if the source of infection in the thenar space is tenosynovitis of the index. Slight movement of the interphalangeal joint of the thumb will be permitted as the tendon is not involved.

The purpose of surgery is to liberate pus under tension in the thenar space and this is best approached by means of a curved incision along the radial and dorsal aspect of the index, passing along the ridge of the web to the metacarpo-phalangeal joint of the thumb. An artery forceps is passed into the swelling and opened in the Hilton manner, deep to the tendon of the index finger The space is entered and if pus is present it will be easily liberated. A rubber drain has to be inserted for forty-eight hours to prevent premature healing, at the end of which time, if the antecedent infection is in control, the thenar space infection will rapidly reduce itself and healing will be complete in a week.

CHAPTER 5

INJURIES TO TENDONS

TENDON DISINSERTIONS

By definition, a tendon is disinserted when it is detached from its attachment to bone or its origin from muscle. It results from abnormal force or muscle contraction. The proposition has been made that it is impossible to rupture a normal tendon. If sufficient force is applied to a tendon it will disinsert itself, either from its origin or from its insertion, but will not break in its course.

If the site of a tendon rupture, for example the tendo Achillis, is examined histologically immediately after injury, it is found that changes are present which evidently precede the trauma. Some of the tendon fibres are degenerate and others are replaced by fibrous tissue; the picture is one of established degeneration.

If a finger should be avulsed from the hand by machinery, the tendons are drawn out of the arm and disinserted from the muscle. Histological examination of these tendon ends reveals normal tendon tissue. Unless this very injury is inflicted on the leg of the Christmas turkey, the ossified tendons which are permitted to remain may produce some very unpleasant ' bone in throat ' episodes. McMaster of Chicago has demonstrated, experimentally, that a normal tendon has to be divided at least half-way across before it will rupture rather than disinsert. It follows that if a tendon is ruptured in its course, that tendon must have been abnormal before the injury. The importance of this observation is apparent when repair is considered. A tendon which is ruptured in its course is abnormal. The methods of repair are specialized as the tissue to be united is degenerate.

Disinsertion of the Flexor Profundus Digitorum

This is not a frequent injury and is always caused by violence. It happens in the young. A sudden hyperextension force or unexpected resistance to a grasping action are typical injuries. Acute pain is experienced in the finger, often extending up the forearm. After the hyperextension force the patient's attention is concentrated on the interphalangeal joints which, having been sprained, are painful and stiff. Inability to bend the finger is put down to stiffness of the joints. Often the patient does not seek advice concerning the tendon until three or four weeks later, by which time the sprain of the joint is improved, and then it becomes obvious that the inability to flex the terminal joint is due to loss of tendon function.

If the flexor profundus tendon is ruptured during resisted muscular contraction, as for example grabbing at an opponent's pants in a game of rugger, the joints of the finger will not be sprained. The finger itself will

be painless but useless and the patient will seek advice sooner. There may also be complaint of a tender lump in the palm which is the crumpled tendon which flicks into that site at the time of injury. The sole disability due to disinsertion of the deep flexor of the finger is inability to bend the terminal joint. In many occupations this may matter little but such a loss of control is disastrous in the left hand of a violinist and is a considerable handicap to a pianist or typist.

Treatment. In assessing the need for treatment, the surgeon must be sure that the patient is disabled by the loss of active flexion of the terminal joint and not by the sprained finger joints.

If the patient needs controlled flexion in the terminal joint, reattachment of the tendon should be attempted. The terminal part of the digital sheath is exposed by the conventional L-shaped incision. Sometimes it is possible to ' milk ' the tendon up the sheath if retraction has only been slight. If the tendon end comes into view it is pulled down with the finger flexed and transfixed with a straight needle to prevent retraction. The tendon end lies snugly in its appointed place and can easily be reattached to the phalanx by the method described on p. 39. If the tendon cannot be found through a limited terminal incision, it will be coiled up in the palm and it is necessary then to thread it back through the bifurcation of the sublimis tendon before reinserting it into the terminal phalanx. In theory this sounds attractive, as the tendon sheath is not involved in any way and the only damage is to the tendon end which is to be attached to the bone. Unfortunately, however, the tendon sheath does not remain empty for anything more than a few weeks. The space becomes obliterated by proliferation of the endothelial lining. The bifurcation of the sublimis tendon if not kept open by the profundus becomes similarly blocked. Although it may be possible to thread the tendon back through its sheath, it is unlikely that smooth gliding function will be restored if more than one month has elapsed between injury and surgery.

The exact position of the palmar incision varies according to the finger involved (see Fig. 7). The tendon is soon found bulging from beneath the sublimis and it is hooked out A malleable hooded probe is passed into the finger sheath, deep to the sublimis tendon. It passes through the bifurcation and emerges in its correct position at the terminal joint. The probe has to be juggled about until the correct path is found; a false passage is not permitted. The end of the profundus tendon is held into the hood of the probe and the whole lot is pulled through the sheath to appear at the terminal phalanx. The tendon is transfixed by a needle to prevent retraction and reattached to the terminal phalanx.

If the tendon is reattached within a few days, or at least a week or two from the injury, the result will often be perfect. As time passes success recedes and after six weeks it should not be attempted as it is likely that normal function of the sublimis will be upset.

In the case of an artisan who complains of the tender lump in his palm but who does not demand intricate use of his fingers, the only treatment

necessary is to remove the coiled-up profundus tendon from the palm. A short, transverse incision is made exactly over the lump. The tendon is hooked out as it lies quite free. As much as necessary is removed and the skin is sutured with two or three stitches.

Replacement of the ruptured profundus tendon by a palmaris graft is not to be advised. Sometimes active and independent movement of the grafted tendon does occur, but usually it is small in amount and of no advantage. More often the graft has the effect of restricting the function and excursion of the sublimis tendon. It is not good practice.

In long-standing instances, where it is obvious that the patient has real disability, the best treatment is arthrodesis of the terminal joint in 30 degrees of flexion. This will give a strong, stable, painless and useful terminal phalanx and the result will be appreciated by the patient. A method of arthrodesis of the joint is described on p. 100.

Disinsertion of Flexor Sublimis Digitorum

This is an unusual injury. It is of no great account but it causes rather more disability than one would suppose. It is caused by a forcible hyperextension of the proximal interphalangeal joint, without similar force being applied to the distal joint. At the time of the injury it is evident that the joint has been sprained and for several weeks afterwards tenderness and fusiform swelling will dominate the scene. As extension of this joint is restored a disability develops. Although during the course of flexion of the finger the flexor profundus can do everything that the flexor sublimis does, the latter is necessary to initiate flexion of the proximal joint. The ' angle of approach ' of the sublimis tendon, created by its situation superficial to the profundus, is necessary and sufficient to initiate flexion. The profundus tendon with no ' angle of approach ' is unable to start flexion of the proximal joint if the sprain has permitted the joint to extend beyond the straight position. Disinsertion of the sublimis tendon results in a nasty looking deformity when an attempt is made to bend the finger (Fig. 62). More often, probably, the sprain limits joint extension, so the deformity is never produced and the disinsertion passes unnoticed; the injury is labelled as a sprained finger.

Treatment. If the deformity is giving rise to trouble, the only way of assisting the patient is by producing slight fixed flexion of the proximal joint. The easiest way to obtain this is to damage the anterior capsule of the joint. An incision is made on the lateral aspect of the finger and the front of the joint is exposed by retraction of the profundus tendon. The capsule is scarified and damaged, the wound is sutured and the finger immobilized for a week with the joint slightly flexed. It is not an operation to be forced on a patient but if treatment is required it is useful, although occasionally more fixed flexion is obtained than is desirable.

Disinsertion of the Extensor Communis Tendon (Mallet Finger)

This disinsertion occurs more frequently than the two already

mentioned. It happens in young and old alike. Often caused by trivial injury, it is just as liable to occur in the machine shop or on the games field as in the home. The disinsertion of the tendon from the distal phalanx results from stubbing the finger, producing a sudden flexion of the terminal joint whilst the finger is being actively extended. Usually only one finger is affected. Stubbing the finger hurts locally but is accompanied by pain which shoots up the back of the hand. The patient's attention is instantly concentrated on the back of the joint and the main complaint in the first instance is of local pain. Active extension of the tip of the finger is not possible, but this does not seem at first to agitate the patient whose main preoccupation is with pain and tenderness. The

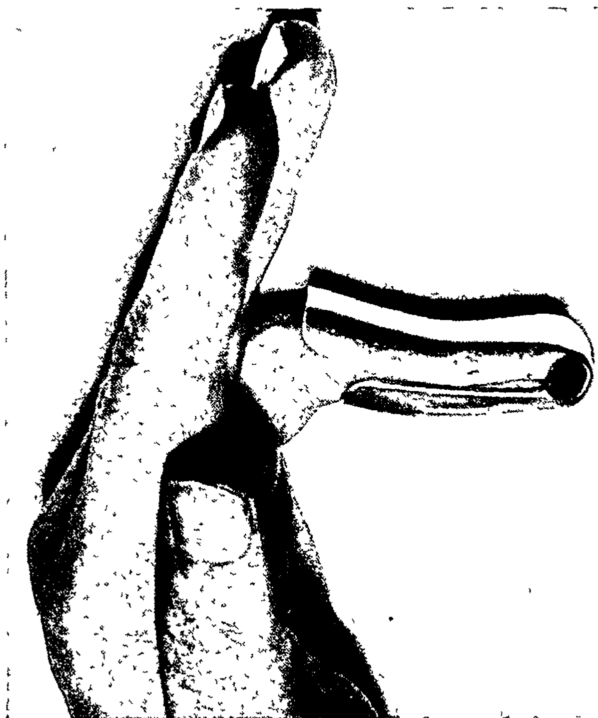


FIG. 37 This is a typical form of the less complex type of mallet finger splint

surgeon knows that the tendon is pulled away, and is apt to be obsessed with the absence of active extension of the joint which he can see rather than with the pain which he cannot feel. If the injury is more severe, a small flake of bone from the terminal phalanx may be avulsed by the tendon. This is more likely to cause some intrinsic stiffness within the joint than a simple disinsertion of the tendon.

Treatment. Tradition demands that the patient should be put to great inconvenience in order to give the tendon the best chance of re-establishing its insertion into the phalanx. To this end splints have been devised with the idea of relaxing the tendon, thereby making spontaneous coaptation more likely. The distal joint of the finger is held hyperextended whilst the proximal interphalangeal joint is held flexed.

This position effectively neutralizes any extensor effect on the tip joint. A plaster, or a prefabricated aluminium splint, is applied to the finger and the patient is sent away with the silly instruction to wear it for six weeks without removal (Fig. 37). After this treatment the end result is good and although the finger seems a little flexed for some weeks after the splint is removed, the patient ceases to complain and full function is restored. It should be realized that the patient is concerned with pain as well as loss of function and will be dissatisfied as long as pain remains. Time alone is necessary; and finally the patient will be satisfied whatever the state of the tendon. Enthusiasts are apt to undertake operative suture of the avulsed tendon. When the approach has been made through an L-shaped incision, a few local stitches attaching the tendon to base of phalanx may satisfy the surgeon. Surgery is usually unnecessary; it is, however, a good method of persuading a patient to wear a splint while nature is healing the tendon. Afterwards the finger will be straight though a bit stiff.

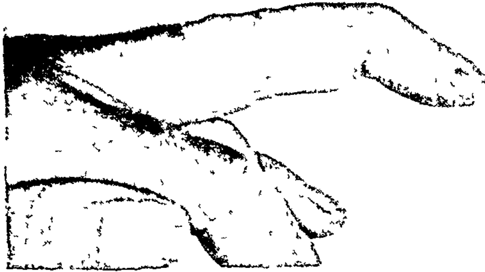


FIG. 38 (*a*) Typical mallet finger. The patient was a cowman and could not accept traditional treatment

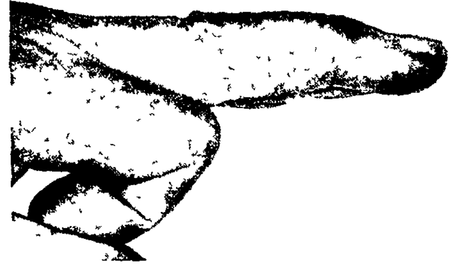


FIG. 38 (*b*) He had no treatment at all, presumably he needed none

If the patient is sufficiently intelligent and the doctor sufficiently persuasive, probably the best treatment for this injury is to ignore it. The patient is warned that pain will persist for several weeks; that swelling may remain for a longer time and that active extension will not be present for some months. Indeed, active extension may always be a trifle deficient, though serviceable function will be enjoyed (Fig. 38). It is odd that often the deformity will reduce itself with no treatment. Sometimes the lateral fibres of the tendon remain intact and these may form a scaffolding for spontaneous repair. Spontaneous improvement explains why the result is good when the patient only wears the splint to show to the doctor; the rest of the time it being in her handbag. If the patient is not very intelligent, some lip-service splint should be applied as a visible sign of treatment. When a small fragment of bone has been avulsed a painful and partly stiff joint is the usual result.

Avulsion of Fingers

Nearly every medical museum has a pot in which is suspended a single finger with three long tendons attached to it. This represents avulsion

of the finger due to great violence. The avulsion may take place at the proximal interphalangeal joint or at the metacarpo-phalangeal joint, but in either instance the three tendons attached will be pulled out of the forearm. Such injuries now are less common than they were since machinery in workshops is better guarded. The injury is only notable as an example of disinsertion from muscle rather than bone.

Clearly there is no treatment except to suture the laceration on the hand from whence the finger has been wrenched.

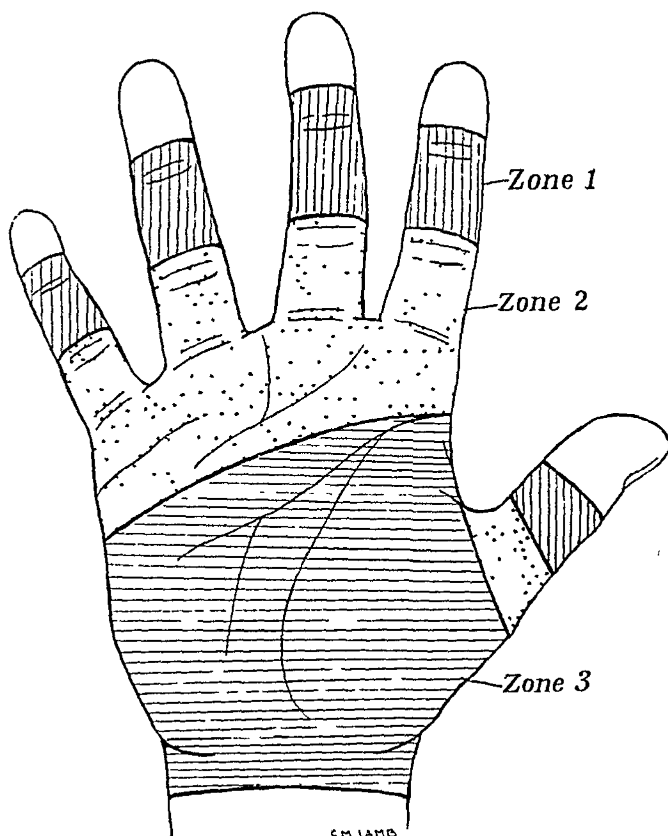


FIG 39. Probably the most frequent site of tendon injury is at the junction of Zones 1 and 2 This results in division of the profundus and partial division (with adherence) of the sublimis

TENDON DIVISIONS

The Flexors

The disability following division of flexor tendons in the fingers is significant and may be crippling. An accidental division of the profundus tendon of the little finger in the left hand probably causes no trouble at all, whereas division of both flexor tendons at the base of the index or middle finger of the right hand will cause a good deal of disability.

Twenty years ago responsible medical opinion was apt to advise amputation of a finger in which both tendons had been divided if the patient wanted to use his hand and not just look at it. Pioneer work, however, had been going on for a good deal longer, but the knowledge

was not generally disseminated. The names of Sterling Bunnell of San Francisco and of Sumner Koch and his associates in Chicago are known to every surgeon interested in the hand, as they were among the first to approach the problem in an intelligent manner. The old faulty technique of suture was discarded; the true principles were discovered and used and a new intelligence and ingenuity were applied to assure an improved result. Now that this knowledge has been disseminated and in some ways enhanced, surgeons generally are able to improve on the results of their surgical forbears. The major problem remaining is one of technique.

When considering the repair of flexor tendons in the hand, it is customary to divide the course of these tendons into three zones. The reason for doing this is that the anatomy in the three zones differs and the methods of repair applicable to injuries in one zone may not stand any chance of success if applied to an injury in another (Fig. 39).

Zone 1. This is the territory occupied by the profundus tendon lying alone in the digital sheath and extends from the proximal interphalangeal joint to the tendon insertion in the terminal phalanx. In the thumb this zone extends from the middle of the proximal phalanx to the tendon insertion.

Zone 2. This is the zone in the finger and palm, extending from the beginning of the digital sheath, at the level of the transverse palmar creases, to the proximal interphalangeal joint where it joins with Zone 1. The sheath contains two tendons, having independent action one on another. In the case of the flexor longus pollicis this zone extends for an inch on either side of the metacarpo-phalangeal joint.

Zone 3. This comprises the palm, extending from the carpal ligament to the entrance of the digital sheath. Here the finger tendons lie close to each other, surrounded by paratendon together with the lumbricals and accompanied by the digital nerves. The region deep to the thenar muscles comprises Zone 3 for the flexor longus pollicis.

Diagnosis

In the cold light of after-knowledge it may seem incredible that a tendon division is not diagnosed instantly on first inspection of a damaged hand. Always when major tendon damage has been sustained, a change in attitude of the digits is to be noted. A finger may be dropped or it may lie unduly straight; its posture is out of context with its fellows. After an initial critical look at the hand the patient is asked to make those movements carried out by tendons that could conceivably be damaged. At the same time a simple nerve examination is carried out. A tendon division is often overlooked if the skin wound is trivial, because the abnormal attitude is not noticed. Examination for loss of tendon function is easier in such instances and the results should be pointed out to the conscious patient before primary surgery. The individual action of the tendons of the hand is common knowledge and any discrepancy should be investigated clinically or at surgical inspection.

A Policy of Treatment

It would seem to be desirable to sew up a cut tendon at the time of skin suture, but there are difficulties about this. It is unusual for the tendon ends to remain beneath the wound and so be readily available for suture. It is even less likely for the original wound to be so disposed as to give adequate access to the tendon ends, even though not retracted. The finger is nearly always flexed when cut. When it is straightened in preparation for operation, the distal cut end of the tendon recedes away from the wound. The proximal end is liable to retract because it is attached to muscle. This retraction may not be great but in any case the wound will have to be enlarged in order to undertake an immediate tendon suture.

The wound is contaminated. Enlargement of the contaminated wound may spread infection, should this develop. The likelihood of this depends on the amount of contamination, degree of tissue damage and the time elapsed since wounding. Fingers are usually very contaminated. The degree of tissue damage, an index of resistance to contamination, is more easily estimated. An incised wound obtained in the kitchen is less liable to become infected than a laceration caused by a lathe or other mechanical contrivance. If the tissues are crushed, local resistance to contamination is automatically diminished and it would be unwise further to enlarge the incision in order to find the tendons.

The original wound may be so arranged that in order to enlarge it a flap with an inadequate blood supply would be formed. Resistance to infection would be further diminished. This does not mean that the skin flap will slough but the vitality may be diminished sufficiently to prevent healing by first intention. These considerations do not carry as much weight now as formerly, since the almost universal availability of antibiotics. But antibiotics cannot reach a contaminated location with a poor blood supply; they cannot clean Augean Stables, especially if they are not permitted to enter. The time factor is important but it should not frighten the surgeon. It is interlocked with other factors, namely the amount of crushing and contamination.

Another factor to consider is whether the necessary skill is available. Tendons are frequently damaged in the factory or machine shop but accidents in the home account for a significant proportion of all tendon injuries. Patients with divided tendons are distributed according to the population, whereas surgical skill is concentrated in the towns. A patient with a divided tendon is sent off to the nearest hospital irrespective of the skill available. There he may be received by a surgeon who, though keen, knows little of tendon injuries. The necessary instruments may not be available. The ordinary soft part operating set, which is generally available in this country, is more in keeping with a post-mortem examination than with the *haute couture* of tendon repair. Only plastic or neuro-surgeons, as a routine, use instruments of sufficient delicacy to do this work. A patient arriving at the hospital with a divided tendon

falls outside the normal surgical routine. He is delayed in the Casualty Department, put last on the operating list and left to the mercies of a junior surgeon who is tired after a long day of assisting. A junior nurse handles the instruments without skill or knowledge. A ramshackle suture is completed but tendon function is not restored.

Like other difficult decisions, each instance must be judged separately. The decision to be content with skin suture only or to go on to primary tendon repair has to be made. The surgeon will bear in mind whether the hand is extensively and heavily contaminated before the accident; whether the cut is clean and amenable to enlargement according to surgical principles or whether it is lacerated and so contused as to make primary healing unlikely. Further, he must consider the time interval between trauma and surgery and finally decide whether he has sufficient skill to carry out delicate tendon surgery.

Generally, it is advisable to err on the side of caution and to suture only the skin. In the best circumstances the result of a successful immediate tendon suture is only just superior to that of a delayed primary suture. What is more important is that the results of late tendon surgery are not so good where primary surgery has already disturbed the field and failed. Many surgeons feel the routine to be followed in the first instance is that the skin alone should be sutured, but they would be willing to vary this routine should the circumstances be exceptional, such as available skill or the favourable condition of the original wound.

A good policy, therefore, which should be instituted unless other circumstances dictate, is that the patient is admitted, the hand is examined and the tendon deficiency is noted. The wound, after adequate preparation, is then sutured, the tendons being left alone. The next day passive movement to the digit is encouraged. At the end of ten or fourteen days, when the stitches have been removed, the finger will not be restricted in its motion. A delayed primary suture can now be carried out in circumstances which are favourable.

TREATMENT

Zone 1

(*a*) **Immediate Suture.** The disability from a cut tendon in Zone 1 is slight and if the finger is otherwise normal the loss of terminal flexion is often no handicap at all. The disability will depend on occupation. The picture of an almost normal hand must always be in the surgeon's mind as he operates on lesions of Zone 1 (Fig. 40).

The conditions are similar to those of the disinserted flexor profundus tendon. Almost always, and certainly if the wound is transverse, it will have to be enlarged in order to find the tendon ends. Whether this is wise or possible will depend on local conditions, such as the estimated degree of contamination, direction of accidental cut and the time elapsed between injury and submission to surgery. If it is thought admissible to do a primary suture, the enlargement is carried distally along one side

of the finger, until the end of the tendon is easily in view. Further enlargement along the opposite mid-lateral border of the finger is carried proximally until the proximal end of the tendon is found. Frequently the profundus tendon does not retract very far, being held by the vinculum longum. The cut end may be at the level of the bifurcation of the sublimis tendon. If the tendon end has retracted into the palm, repair is beyond the scope of primary surgery. The skin wound alone should be sutured. A compression dressing is applied and movement in the finger should be restored as soon as possible.

A patient presenting himself with a small cut on the end of the finger is not conditioned to ambitious surgery. A minor degree of infection that does not suppurate is enough to stick up the undamaged sublimis



FIG. 40 It is not worth while expending great effort to correct this disability.

tendon If more than small local enlargement is necessary, the wound should be sutured and permitted to sterilize itself. Furthermore, the patient will have a chance of assessing the reality of his disability.

If the tendon has been obliquely divided, suture is simple. The method is described on p. 29. The after-treatment is important. The other fingers should not be permitted complete freedom of active flexion because the profundus is an undifferentiated muscle and all contraction effort will act on the affected finger. In spite of the triviality of the injury the wrist should be splinted in palmar flexion for three weeks after oblique suture, otherwise an apparently satisfactory suture line may pull apart.

If the division of the tendon is transverse in direction, the suture is more complicated. It is probably better to use the withdrawable technique of Bunnell, described on p. 30. The limitations laid down as to the after-treatment of an oblique suture do not apply in this instance, because the withdrawable wire technique temporarily inserts the tendon into

the nail and the hold on the tendon is firmer. The after-treatment is described in Chapter 6.

(*b*) **Delayed Primary Suture.** A delayed primary suture may be defined as follows: there is a delay between injury and suture but the technique of suture is identical with that for primary surgery. The tendons have not become adherent, nor do the ends need to be freshened. During the interval between primary skin suture and the delayed primary suture of the tendon the wound has had time to sterilize itself. The shortest possible time should elapse between the original injury and the delayed primary suture otherwise the tendon sheath is apt to become obliterated by proliferation and hypertrophy of the endothelial lining. Free gliding of the tendon after suture becomes less likely with increasing delay. After skin suture, and whilst healing is taking place, every effort should be used to restore passive movement, so that when the stitches are removed the finger is in a fit state for exploratory surgery. It is obvious that tendon suture in a finger with stiff joints is a waste of time.

The chance of success of delayed primary suture is equal to that of a primary suture. There is the added advantage that the contaminated wound has been sterilized automatically in the intervening time. The only possible disadvantage to delayed primary surgery, is that if for one reason or another the tendon suture is delayed longer than three or four weeks from the original injury, the chances of success are not great and the operation may not be considered worthwhile.

The technical methods are exactly the same as for an immediate suture. The withdrawable wire technique is more often used, perhaps, because if the tendon appears a little friable this method will ensure a firmer hold (Fig. 41). If the tendon has widely retracted it will have to be sought in the palm and reinstated by the method described on p. 30. The actual suture will be by the withdrawable technique, whatever the direction of the division.

(*c*) **Tendon Advancement.** At a time suitable for delayed primary suture there is another method sometimes used to restore tendon function. Consider, for example, the instance of the profundus tendon which has been divided over the middle phalanx, about 1 inch from its insertion. If the cut end of the tendon could be advanced to the point of insertion on the terminal phalanx, a suture line in the digital sheath would be eliminated.

Method. The tendon is exposed in the finger at the site of injury and the distal end is excised to its insertion. The proximal end is identified. Another incision is made above the wrist, exposing the flexor tendons. An L-shaped incision is suitable but its exact position depends on the tendon to be sought. The profundus tendon in question is identified, surrounded by normal mesotendon. The tendon is sectioned in a Z-shaped manner permitting elongation of the necessary amount. The peripheral end is again exposed and the tendon is drawn down into contact with the terminal phalanx. Only limited advancement is possible as the

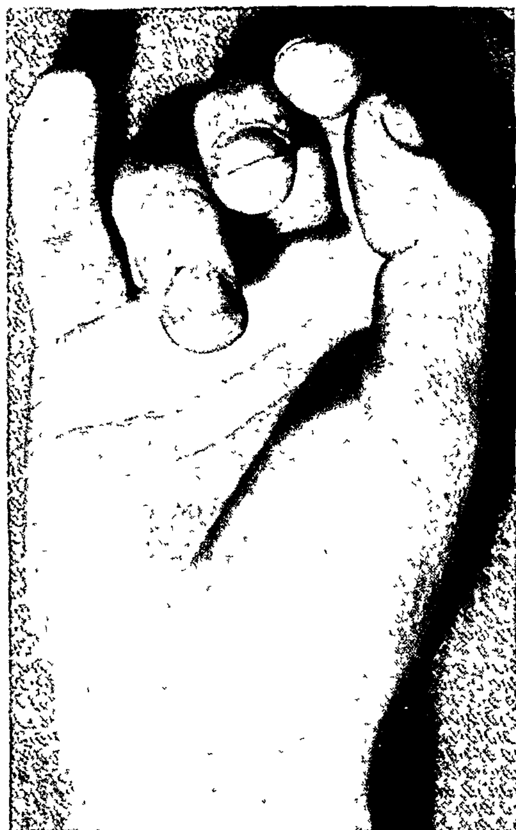


FIG 41 (*a*) The flexor profundus to the minimus has been divided, resulting in an alteration of attitude at rest. Delayed primary suture was carried out



FIG 41 (*b*) The profundus is seen emerging through the bifurcation of the sublimis. The suture is in position and about to be secured.



FIG 41 (*c*). An adequate result was obtained

tendon is tethered by the mesotendon. One inch is probably the maximum and it is unwise to attempt more than this. The tendon is made adherent to the terminal phalanx in the normal manner by a chromic catgut suture perforating the nail, having penetrated the phalanx. At the Z-lengthening two 00 catgut sutures are all that are required to coapt the tendon within its mesotendon. The wrist is held flexed for three weeks to allow normal healing and at the end of this time good function will be restored. The lumbrical is slackened but this gives rise to no clinical disability. This is an adequate alternative to delayed primary suture for injuries in Zone 1.

(*d*) **Secondary Suture.** A secondary suture is defined as follows: the tendon is prepared for suture by the same methods as previously described for delayed primary suture but special provision has to be made to obtain gliding movement.

After a time the lining of the tendon sheath proliferates sufficiently to obliterate the tunnel. A passage has to be forced to reinstate the tendon and this provokes adhesions preventing future movement. A tendon suture six weeks or more from the original injury constitutes a secondary suture. The timing of a delayed primary and a secondary suture merge imperceptibly together. Secondary suture, in general, is not very satisfactory. It abounds with pitfalls and in particular is rarely justified in lesions of Zone 1. The technique is described on p. 27.

Occasionally it may seem justifiable to suture a retracted profundus tendon and wrap it with forearm areolar tissue; sometimes it may seem wise to re-operate on a previous primary suture, failed by reason of adherence, and to wrap the adherent tendon with areolar tissue. Rarely a palmaris graft may be inserted and threaded through the intact sublimis to replace the divided profundus. Never must an intact sublimis be sacrificed during the course of repair of a profundus tendon injured in Zone 1.

(*e*) **Tenolysis after failed Primary Suture.** Either type of primary suture may fail to result in the looked for motion. Doubtless there is adherence at the suture line.

There are occasions when tenolysis of the sutured profundus in this Zone may seem useful, but they are infrequent. If the adherent profundus is partially obstructing the sublimis action, it is better to stabilize the tip joint with a tenodesis and withdraw the rest of the profundus through a palmar incision.

If the sublimis tendon is working normally, and the sutured profundus is totally adherent, a case can be made for tenolysis. The timing and technique of the procedure is described on p. 33.

The Flexor Longus Pollicis

This tendon is as important as any other individual deep flexor. The methods of treatment of deep flexor injuries apply in this instance with equal force. Primary sutures and delayed primary sutures give good

results (Fig. 42). The free tendon graft is especially useful in late instances. Good movement and control are obtained, but excursion is rarely full. Finally, if all else fails, a tip joint arthrodesed in 45 degrees of flexion gives a serviceable thumb.

Other Methods of Restoring Function Following Tendon Division

(*a*) **Arthrodesis.** If real disability is apparent because the tip joint cannot be flexed, arthrodesis is available when other methods have failed. Thirty degrees of flexion is probably the favourite position. There are some occupations which demand stability of the terminal phalanx and in these instances arthrodesis of the joint is not only reasonable but it is

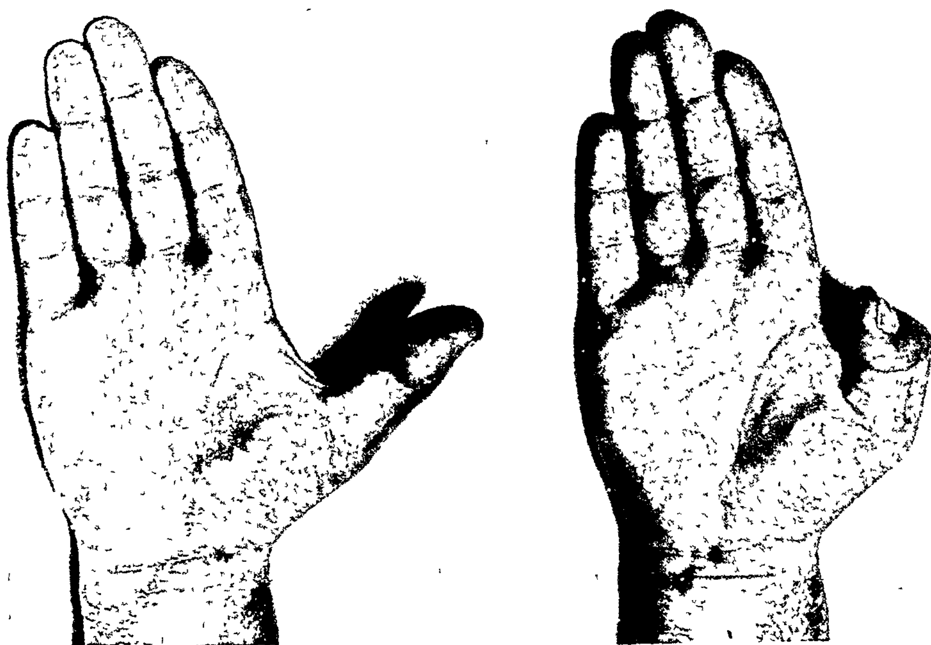


FIG. 42 The result obtained after a delayed primary suture of the flexor longus pollicis divided in Zone 1

effective The circumstances are similar when the profundus tendon has been avulsed.

Method. The joint is easily destroyed but because the necessary splintage is disproportionately cumbersome and apt to be ineffective, failure is frequent.

The joint is exposed through an L-shaped dorsal incision and the articular cartilage is destroyed by nibbling forceps. The best fixation is obtained by Kirschner wires placed obliquely across the joint. The wire enters the lateral aspect of the terminal phalanx near the nail bed and crossing the joint enters the middle phalanx obliquely. Similarly one is put in from the opposite side. They are cut off short, but still protruding, and the skin is sutured. If the fixation is good only a simple gauze dressing is required. When the stitches are removed a small plaster of Paris

splint is applied, which is to remain in use for three months. The wires should be removed at two months from operation and the splint reapplied for one month. Often the wires have to be removed earlier because of mild infection. The arthrodesis is often unsound.

(*b*) **Tenodesis.** Because the results of an arthrodesis operation are not always good, some surgeons prefer to rely on tenodesis. Such an operation is not possible after a disinsertion of the deep tendon, but following division of the profundus tendon over the middle phalanx there is sufficient stub of tendon to be attached to the middle phalanx. If a sound tendon insertion can be made the results are as good as those following a successful joint fusion and without the irksome splintage.

Method. At operation the tendon is exposed by a lateral incision over the terminal and middle phalanges. The volar aspect of the middle phalanx is rawed and the tendon is held in contact with it by catgut stitches holding the tendon to remains of sheath and periosteum. Adherence is bound to follow. If at the same time the distal joint is opened and damaged, this will make doubly sure that the finger tip will remain flexed. The wound is sutured and a plaster of Paris splint is applied, holding the tip of the finger sufficiently bent. The final position will be held by a combination of tenodesis and fibrous ankylosis but the result is effective. The result is obtained more easily than by arthrodesis and at the end of a month the finger can be liberated and increasing use can be allowed without fear that extension of the joint will take place.

Zone 2

The essential difference, apart from locality, between Zone 2 and Zone 1 is that in the former there are two tendons present which have to work not only freely in the sheath but independently of each other because of their different amplitude of excursion. A secondary difference is that the important pulley which holds the tendons close to bone and prevents them starting forward under stress, is in this zone. There is an evident difference between the thumb and finger in Zone 2 The observations related to this zone are directed chiefly to problems of the fingers but they are applicable to the thumb as far as anatomy permits.

(*a*) **Immediate Suture.** The finger is nearly always bent when the tendons are divided and free retraction of both ends is the rule. A wide exposure has to be made in order to reach the ends and bring them together to make suture possible. It is never wise to suture both tendons. It has been found to be impossible to get two suture lines to move not only independently of each other but at all. Inevitably, if both tendons have been divided, the sublimis tendon is to be sacrificed. If it is decided the wound is clean enough and that it may be elongated, this is done and the proximal end of the sublimis is pulled down and cut off as high as the incision will permit. The distal end has to be removed from its insertion, sometimes through a separate incision at the proximal interphalangeal joint. A lateral longitudinal incision is best for this; the digital nerve is

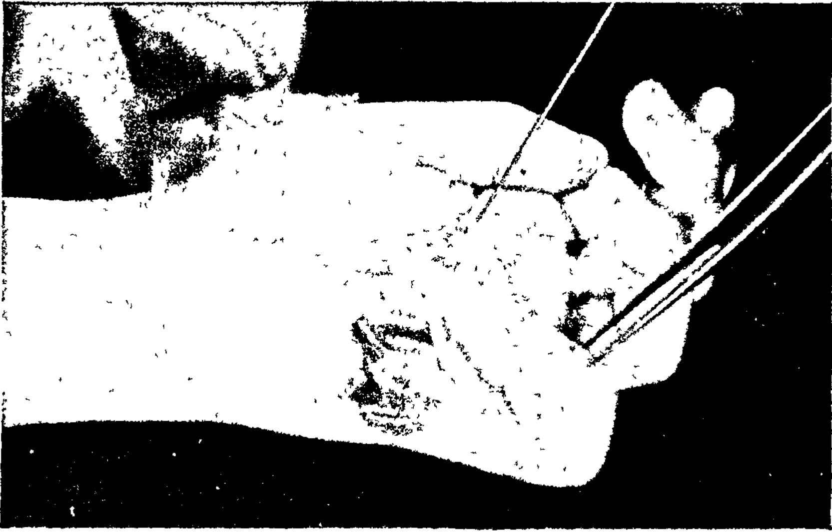


FIG. 43 (*a*). Division of both tendons in Zone 2. The sublimis was sacrificed and a delayed primary suture was carried out





FIG 43 (*b*) and (*c*) The result is poor because of adherence of the suture line to the transverse metacarpal ligament A free graft might have been used with a better result

avoided and the profundus tendon is seen and retracted volarwards. The flat, straplike tendon of the united sublimis is seen over the middle phalanx and divided. The distal end of the tendon is removed.

If the profundus happens to have been divided obliquely, local interrupted sutures of fine wire are used. If, however, there has been a transverse cut, the best form of suture is by the withdrawable method of Bunnell. If the proximal end of the profundus tendon has retracted into the palm the injury is not suitable for immediate suture. It is better, after removal of the sublimis, to close the skin and plan a delayed primary suture.

The pulley or thickening of the digital sheath over the proximal phalanx will almost certainly have been divided either by the injury or by surgical exposure. Endeavour should be made to preserve the pulley by dividing it to one side, and not centrally, but it is never necessary to reattach it to the phalanx. If a compression contour dressing is applied and allowed to remain *in situ* for three weeks skin suture only is needed. The pulley is able to reconstitute itself and perform its functions.

The results of primary suture are not always good but if adherence of the suture line mars a good result, the initial surgery is to be considered as a first stage of a two-stage procedure; the second being to create a gliding mechanism.

Many surgeons are more emphatic about the need for simple skin suture in Zone 2 than in Zone 1 as a first-aid measure for cut tendons. After finger mobility has been restored a delayed primary suture is favourable because the incision can be suitably planned, using appropriate skill and instruments.

(*b*) **Delayed Primary Suture.** A delayed suture is carried out as a set piece. The healed scar of the injury denotes the centre of the exposure. The incision lies along the lateral border of the finger. It extends distally as far as necessary to expose the tendons. Proximally the incision must be carefully planned in accordance with the rules of skin incision (see Fig. 7). At this stage the palm should be opened through the correct incision for the finger involved. The tendons are inspected. The end of the sublimis tendon will be lying free, in which case it should be pulled down and cut off as high as the palmar wound will allow. The distal end of the sublimis tendon must be removed through the finger incision if this has not been done already. If the sublimis tendon is in continuity, in spite of being damaged, it must be removed because assuredly adherence will follow and function will not be restored. Again the tendon is divided high in the palm and separated from its insertion. The tendon sheath is preserved as far as possible and damage to it is avoided (Fig. 43).

In a delayed suture at this level it is not wise to use interrupted fine sutures, even if the tendon section is oblique: they will cut out. A through-and-through suture, embracing a good deal of tendon, will be necessary. If the wire is to remain permanently, it is better to use a twisted three-strand suture wire as this does not fragment with movement



Fig. 44 (*a*). Both tendons to annularis had been divided six weeks previously



Fig. 44 (*b*). The profundus has been sutured by the withdrawable technique.

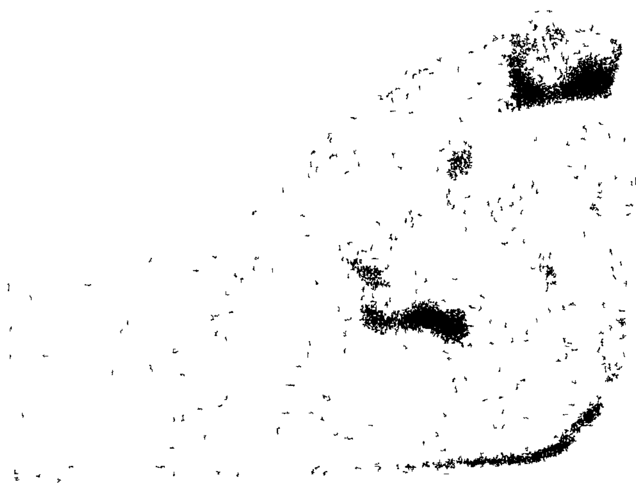


Fig 44 (*c*). Paratendon envelopes the suture line and adjacent tendon. This is the essence of the secondary suture.



Fig. 44 (*d*). The result is moderate and might have been better had a free graft been used.





This normal but adherent tendon may at a later operation be surrounded by areolar tissue to permit gliding movement. In this instance tendon function is restored by a two-stage operation (see p. 33). A primary suture which has become adherent is not a failure. It is to be regarded as the first of a two-stage procedure. It is a space-filling operation that retains the integrity of the fibrous sheath. Moreover, the tendon and muscle are kept in a healthy state by preventing degeneration of tendon and myostatic contracture of muscle.

Other Methods of Restoring Function after Tendon Division

(*a*) **Free Tendon Grafting.** This method of repair is exceedingly popular with surgeons interested in the injured hand. The operation is



FIG 46. This degree of active flexion after a free tendon graft is considered to be satisfactory.

quick and satisfying to the surgeon and the results generally are good, sometimes brilliant. Some experienced and thoughtful surgeons consider no other form of repair for injuries to tendons in Zone 2 (Fig. 45). They are apt to look upon secondary suture as the academic vestige of past endeavour to secure finger movement. This argument applies equally well to the second stage of a failed primary suture. In this instance, instead of performing a tenolysis, many surgeons scrap the adherent tendon and replace it by a free tendon graft. The thumb is considered equally with the fingers (Fig. 46).

The palmaris longus tendon is ordinarily used and should it be absent, a slip of the extensor longus digitorum is suitable. The advantages of a free tendon graft are these; the gliding mechanism is transferred with the tendon, so that the bed in which the tendon is laid is immaterial. Further, the suture line can be transferred from the digital sheath to the palm.

The indications for free grafting in Zone 2 are as follows: a secondary suture is only likely to work in a finger which has not been scarred by infection or laceration. A palmaris graft is more likely to restore function in these instances. In some respects a free grafting operation is easier to do than a secondary suture because the site of injury is not disturbed at all. It is no use performing a free grafting operation unless passive motion has been restored to the finger joints. The technique of free tendon grafting is described on p. 35.

(*b*) **Arthrodesis.** If only one digit has been damaged arthrodesis is not a method used to alleviate the disability of irreparable tendon division. If the finger is a liability it is better removed at an appropriate level. If several digits have been damaged, irreparable tendon loss can be to some extent minimized by arthrodesis of the proximal interphalangeal joints. It may not be necessary to do this if the volar scarring of injury or surgery contracts the fingers. Not infrequently several fingers are involved in an injury that divides flexor tendons. If six or eight flexor tendons are divided in Zone 2, together with a number of digital nerves, reparative surgery becomes a tall order. Attempts, naturally, are made to produce active flexion of the fingers but success of multiple tendon grafts is not always assured. In such an instance arthrodesis of one or more proximal interphalangeal joints may convert a paper weight into a relatively useful hook.

The interphalangeal joints are destroyed through a dorsal incision and bone contact in 45 degrees of flexion is maintained by crossing Kirschner wires. These wires should remain in position for six weeks, if possible. Quite often, however, suppuration demands earlier removal. External fixation by plaster of Paris is usually unnecessary. It is not as easy as might be supposed to obtain a bony ankylosis of the finger joints but fortunately a sound fibrous ankylosis is entirely serviceable.

Zone 3

This zone comprises that part of the palm proximal to the digital sheath that extends to the anterior carpal ligament. Tendon injuries in this zone are often part of an extensive laceration or crushing. These are often industrial injuries rather than casual accidents in the home. Apart from industrial accidents which may be crushing in type, the most frequent cause of division of flexor tendons in the palm is broken glass. A child running with a milk bottle trips up and falls down, cutting the palm on the smashed bottle. Window glass is a frequent cause of tendon destruction in the wrist region and proximal part of the palm. Because tendon injuries in this zone are so often due to lacerations by glass, they are frequently multiple and often accompanied by division of the digital nerves where they lie in close relationship to the tendons.

Diagnosis. During the normal course of examination of a palmar laceration to determine the extent of the damage, the surgeon must also assess the state of the nerve supply of the fingers. It is necessary only to

test appreciation to pin prick. Either the patient can feel the pin or he cannot. It may not be possible to check motor ability, either in the deep branch of the ulnar or the motor branch of the median nerve. Even a cursory check of intrinsic movement is not likely to be welcomed by a patient with a cut palm.

It is probable that an accurate estimate of the amount of tendon damage can be made before inspection in the operation theatre. The fingers, if the tendons have been divided, assume an abnormal attitude. They are extended, whereas they should be flexed. When the palm has been damaged it is natural that the fingers should be held flexed. If both the tendons of one finger have been divided it will be seen that the three remaining fingers are held flexed, whilst the injured finger lies in an entirely abnormal position (Fig. 49a). One glance at the wound will be sufficient to enable the surgeon to decide that further investigation in the operating theatre is necessary. If this decision is made, the dressing need not be further tampered with.

Preparation of the hand for surgery is carried out according to methods described on p. 21.

(*a*) **Immediate Suture.** At inspection of the wound the blood clot is removed and the extent of damage can usually be assessed without enlargement or further exploration. Extensive lacerations with flaps of skin lend themselves to a full inspection of the damaged area. If the palm has merely been punctured by a small particle of glass it will be impossible to improve on the clinical assessment of the amount of damage until the wound has been enlarged. Whether it is appropriate and wise to enlarge the wound at this particular stage will depend on the estimated degree of contamination. In a crushing or grossly contaminated wound of some size, it is much better to clear out any foreign material and blood clot and excise any dead skin edge. After skin suture the palm is compressed by a contour dressing.

If, however, the laceration in the palm was cleanly produced by a knife or by glass, and the hand was relatively clean at the time of injury, it is reasonable to suture tendons, especially if a flap has been raised giving all the exposure necessary (Fig. 47). The nerves are more important than the tendons at this stage and if they have been divided it is wise to identify them and to suture formally or at least co-apt the ends with a stitch.

For the argument relating to primary nerve suture see p. 44.

If the original laceration is not too extensive, suture of the nerve or nerves, does not take a great deal of time, in which case it will be possible to repair the tendons. In Zone 3, usually only the profundus tendon is repaired and the sublimis is sacrificed; but not always. In Zone 2 one tendon only is sutured because two suture lines would become adherent one with another. In the palm local adherence is unlikely to form. If both tendons to all four fingers are divided it is not possible to make a good technical job of eight tendon sutures at the time of initial surgery. It will take too long. In such an instance the sublimis tendons must be



FIG. 47 (*a*). The patient is attempting to clench his fist. He broke a tumbler intending to grind it into an adversary's face.

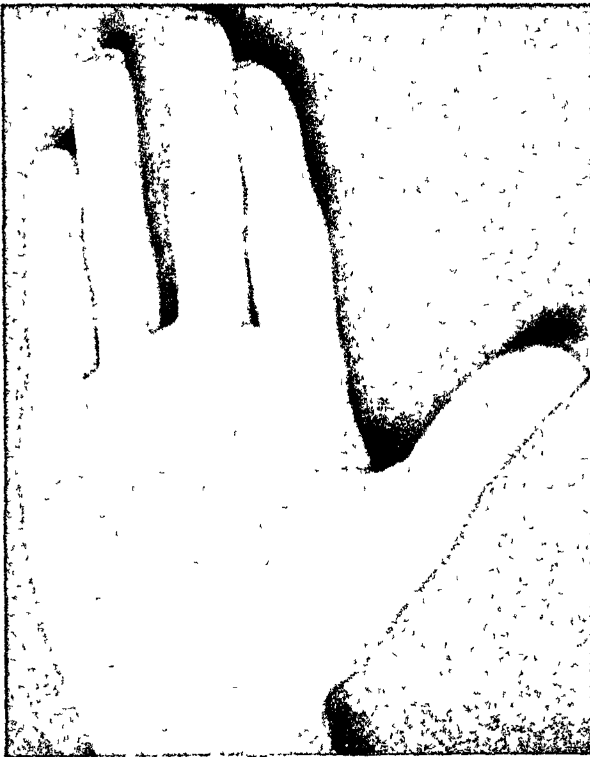




FIG. 47 (*b*) and (*c*) The result of an immediate profundus suture with sacrifice of the sublimis tendons.

sacrificed; the profundus tendons alone are sutured. If, however, the sublimis and profundus to only one finger are divided, both may be sutured; but the absence of sublimis function is hardly a disadvantage, so if there is doubt, the sublimis should be sacrificed.

Removal of the tendon is not as easy as might be supposed. The proximal end is pulled down as far as possible and is divided high in the wound. For the distal end it is necessary to make an incision on the lateral aspect of the finger, at the level of the proximal interphalangeal joint. Both slips of the tendon have to be seen and divided and the fragment of the tendon is forcibly dragged out of the palmar wound, leaving the profundus in entire possession of the finger. The sublimis tendon should be divided before its slips have reunited deep to the profundus. Otherwise, on pulling it out of the palm, the complete loop ruptures the vinculum longum of the profundus. This may not be a good thing. If the sublimis tendon is cut off too short at its insertion, a hyperextension deformity may develop at the proximal joint. If too much is left behind fixed flexion may develop. The happy medium is found by good luck rather than good judgment.

The profundus tendon can now be sutured and the method used will depend on the direction of the cut. If the cut has been oblique, four or five interrupted stitches of No. 40 wire are suitable. If the division is somewhere near the origin of the lumbrical muscle this can be folded round the suture line. If the division of the tendon has been transverse, an interweaving type of suture is necessary, taking purchase through the tendon at least ½ inch on either side of the cut. Use of the Bunnell withdrawable stitch is a matter of personal choice. If used, the button would lie at the level of the webs of the fingers. The muscle would then be short-circuited to this point. After the tendons have been sutured, the skin is sewn up and a contour compression dressing is applied. Pressure is maintained in a ‘ cock-down ’ position for three weeks.

It is of capital importance that the surgeon should not be too ambitious and let his enthusiasm carry him away, leading him to undertake procedures at the time of first surgery beyond the capacity of the limb to accept. If the blood supply of the fingers has been jeopardized by division of both the radial and the ulnar arteries at the level of the wrist, time-consuming surgery is unwise. If this is done in the presence of a defective blood supply Volkmann’s ischæmic contracture of the hand intrinsics may well develop. This deformity, added to the inevitable median and ulnar nerve palsies, reduces the hand to the usefulness of a paper weight. Enthusiasm must be tempered with common sense, and if extensive repair is planned it must be carried out rapidly. Certain tendons may have to be left to a second sitting but at first repair the nerves should be sutured and the more important tendons also sewn up. In general the results of surgery in this region are quite good. Sepsis, if this supervenes, will spoil a good technical job. Sepsis is most likely to occur where a hæmatoma is permitted to form.

(*b*) **Delayed Primary Suture.** It is rather more important that primary suture of tendons should be carried out in this zone than in either of the



FIG. 48 (*a*) and (*b*). This palm was punctured by a piece of steel. No nerves or tendons were damaged but the ensuing fibrosis prevented the medius and annularis from straightening.



FIG. 48 (*c*). This wrist was cut six weeks previously. Fibrosis makes the hand unsuitable for surgery

other two. Often, following a simple skin closure, the opportunity for reparative surgery is delayed more than is at first anticipated. For one reason or another the delayed primary suture has to be put off beyond the

opportune time. Frequently the wound does not heal perfectly because skin apposition has not been all that it should be. The direction and extent of the wound may have impaired the blood supply of the skin, or a low-grade infection may have supervened in spite of the use of antibiotics. Sometimes what seems to be a low-grade inflammation does, in fact, take place in the palm without the signs being obvious and hence the necessary precautions are not taken. On exploration of the palm a dense mass of fibrous tissue is unexpectedly found. The fibrosis is woody in hardness and consists of proliferated paratendon. Reconstructive surgery during the proliferative stage of this fibrosis is doomed to failure. The



FIG 49 (*a*). Both flexors to the index have been divided in Zone 3.



FIG 49 (*b*) The result of a free tendon graft

succulent stage is recognized clinically by the palm being locally tender together with pain on stretching any intact tendon that may be involved (Fig. 48). Delayed primary suture is not possible if fibrosis develops in the palm. Surgery has to be deferred until evolution to adult fibrous tissue is complete by which time secondary repair is appropriate. It is a singular and disturbing complication which may spoil the normal programme of repair of palmar injuries.

If reparative surgery has to be delayed longer than three or four weeks, the tendons retract up into the forearm. When they are ultimately retrieved by division of the anterior carpal ligament they are found to have become degenerate, shortened and fragile, and altogether unsuitable for

suture. The tendons become adherent one to another and free gliding afterwards is obstructed. In such circumstances suture is not possible. Because of the important advantages, tendon suture is undertaken in the palm at the time of first surgery, when in other zones it would be considered unwise.

(*c*) **Later Repair.** At a later time, when in other zones a secondary suture might be appropriate, repair has to be made by free tendon grafting. The massive fibrosis which develops after injuries at the base of the palm or wrist must be permitted to mature before it is excised. If a repair operation is undertaken too soon the grafts have to be placed in an area previously occupied by florid and vascular fibrous tissue which cannot be excised completely.

Sometimes it may be necessary deliberately to wait for six months before it is considered that the tissues of the palm are in a fit state to accept tendon grafts. If passive mobility of the fingers is maintained during the waiting phase the results of tendon grafting can be quite good. Perfection though aimed at, will rarely be achieved (Fig. 49). The tendon grafting can be conducted according to the technique described on p. 35. The effective post-operative dressing of a lacerated palm is as important as the surgery which precedes it (see p. 43).

It may be thought that the development of uncontrolled and amorphous fibrosis in the palm and wrist has been unduly emphasized. This may be so, but it is the major cause of appalling disappointment to the patient and of acute frustration to the surgeon.

The Extensors

Injuries to the extensor tendons are considered in four sections, according to the anatomical site of trauma.

Over the Middle Phalanx

The terminal slip of the extensor tendon is formed by fusion of the two lateral bands which are formed at the level of the metacarpo-phalangeal joint. The separated tendons run along the dorso-lateral aspect of the proximal joint and come together again over the middle phalanx. After fusion, the single tendon passes forward to be inserted in the base of the terminal phalanx.

The region of the middle phalanx of the finger is very liable to be cut. The wound itself may not be very striking but the effect of the division of the extensor tendon is obvious and is similar to the deformity of mallet finger (Fig. 50) When the finger is cut the patient has no doubt that a tendon has been divided, because the terminal joint, though painless, is inactive. In the true mallet finger, however, the patient attributes inability to extend the joint to pain and tenderness.

The wound through which the tendon has been divided, does not always require suture. If the wound is transverse, extension of the finger

is all that is necessary to approximate the skin edges. The patient may not seek advice until forty-eight hours after the injury, in which case, if the wound edges are together, a stitch is not needed. If the wound is gaping, a conventional suture is required.

In this site the extensor tendon does not retract. Therefore, if the terminal joint is extended, both ends of the tendon come to lie so close to each other that they may spontaneously heal. If access to the tendon

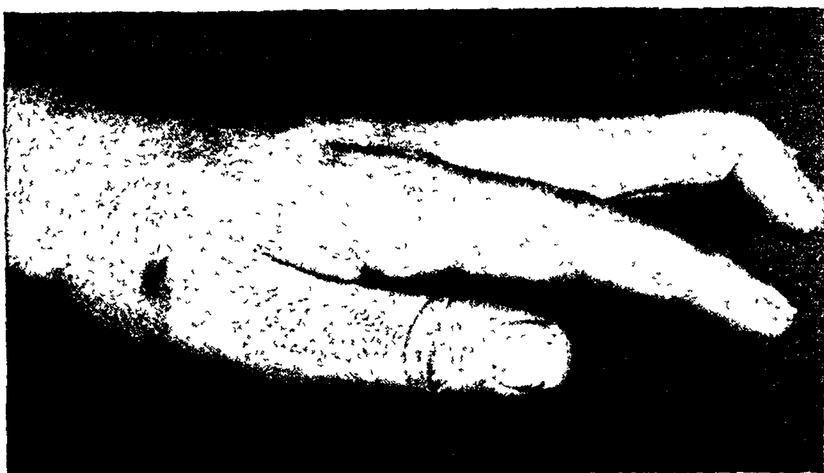


FIG. 50 (*a*) Deformity following division of extensor tendon over middle phalanx



FIG. 50 (*b*). After delayed primary suture adequate active extension is regained.

ends is readily obtained, or if a flap of skin has been raised, it is advisable to suture the tendon at the time of primary surgery unless the skin is particularly contused or the surgeon has reason to suspect heavy wound contamination. If the patient seeks advice forty-eight hours or more after the accident it is better to allow the skin to heal fully and at a later date to perform a delayed primary suture of the tendon. If the wound is gaping after forty-eight hours, a delayed primary suture of the skin is called for.

Technique of Suture. The terminal part of the extensor tendon of the finger is a thin, strap-like structure. Stitches hold with difficulty. For this reason the best method of suture is by using No. 38 steel wire, inserted by the withdrawable technique as described on p. 31. The local variation, in this situation, is that the suture wire is also used as a splint. The wire ends are passed through the distal tendon and brought out through the nail. After the ends have been tied they have the effect of holding the tip joint extended. It should be unnecessary to use a splint after this mode of suture. For a day or two, however, it is wise to use a small splint on the palmar surface of the finger to neutralize flexion forces. For the three weeks, during which the wire remains *in situ*, compression is necessary. This is best applied with tube gauze. The suture is withdrawn in the normal manner. After this it is advisable to support the tip joint for about

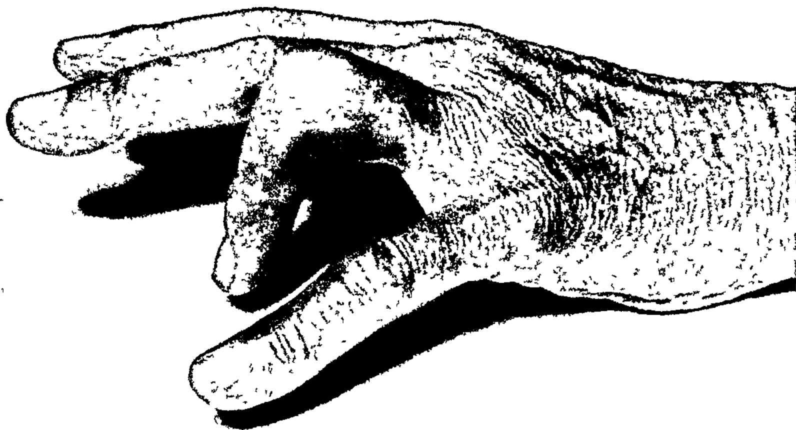


FIG. 51 The change in attitude of the finger when the central extensor slip is ruptured or divided is too characteristic to be mistaken

ten days by a light finger splint. No physiotherapy or after-treatment are necessary.

If the suture has to be delayed so that it falls into the time-group of secondary suture, the difficulties are increased. After a delay of several weeks the tendon ends become stubbornly fixed to the surrounding tissue and mobilization is difficult. It is wise to pause before attempting a secondary suture at this site as the functional improvement will be slight.

At the Proximal Interphalangeal Joint. The dorsal aspect of this joint is quite frequently damaged, both by incisions and by contusion. The extensor expansion divides into three bands over the proximal phalanx. The two lateral bands diverge and, passing to either side of the proximal joint, fuse together to form the single tendon which extends the terminal joint. The central of the three bands passes forward over the capsule of the joint to be inserted into the proximal part of the middle phalanx. It is this middle slip, together with the joint capsule, that is damaged. Active extension is lost and the joint may become irritable (Fig. 51). An irritable

joint is a well known complication of simple trauma. The joint is uniformly swollen in a fusiform manner, by capsular and periarticular thickening; it is tender on lateral pressure over the collateral ligaments and both movements are limited. Such a joint may be troublesome for many months; indeed it may never recover fully.

Treatment. The treatment of a freshly incised wound over the proximal interphalangeal joint is to suture the conjoined capsule and tendon with very fine catgut and then to close the skin. The joint capsule, being less elastic than the skin, may not gape and so may not require suture.

At primary surgery it is not possible to know if the joint will become irritable. A splint has to be incorporated in the compression dressing. A small palmar plaster splint, holding the joint a little flexed is all that is necessary. When the compression dressing and stitches are removed in ten days it will be evident if the joint is becoming irritable. Whether the joint is swollen or normal in appearance the tendon must be protected by continued support for at least two more weeks. A joint that remains unswollen will quickly regain mobility when the splint is removed. If, however, the joint has become swollen and tender, mobility will be slow to return. Coaxed movement with wax baths may be necessary to assist the restoration, and very often these fail to restore full movement. Often damage to the central extensor slip is not suspected at the time of the original cut. The patient may present himself three weeks after injury more on account of persistent swelling than inability to extend the joint. Whilst the joint stays swollen and tender no attempt should be made at reconstruction. Tendon surgery is always inappropriate if the joint to be moved is not mobile. If, however, early suture is not carried out and the joint does not become swollen and irritable, passive range is soon restored after the injury and then the lack of active control becomes obvious. Such a joint is awkward and disfiguring and can be helped by reconstructive surgery; the time for direct suture having passed.

In the main there are two different techniques for repair. One is to expose the joint by a suitably planned flap and when this has been done the lateral slips passing round the side of the joint are elevated from their surrounding tissue and carefully approximated by a few fine thread or catgut stitches, proximal and distal to the joint. The purpose of these stitches is to close the separation of the bands. They are not brought into contact over the whole of the joint. When the extensor tendon is put into action not only will the terminal phalanx be lifted but so also will the proximal joint be extended. Another method of achieving the same result is to expose the joint in a similar manner and taking the palmaris longus, or similar tendon, to pass it across the joint in a diagonal manner. A second strip is passed over the opposite way so as to form a St. Andrew's Cross. The ends of the grafts are sutured to the extensor slips. The results are most capricious but the disability is real and so attempts at improvement are justified.



FIG. 52 (*a*). The tendons have been divided, and the exposed joint may become stiff.

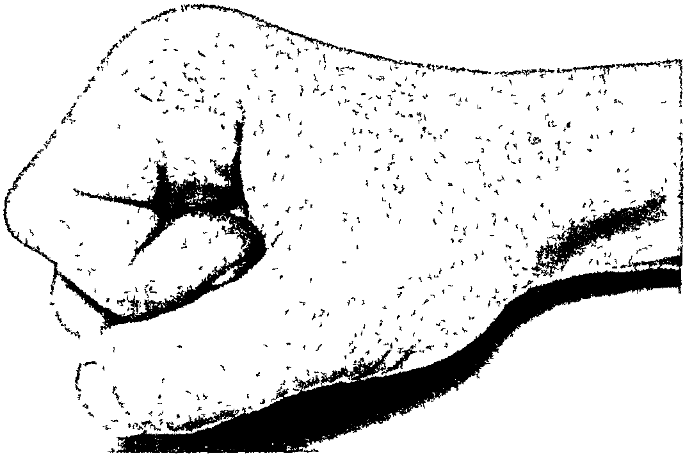




FIG 52 (*b*) and (*c*) The extensor tendon has been sutured and both mobility and active extension have, in part, been restored

Over the Knuckle Joint

Division of the extensor tendon at the level of this joint occurs not infrequently and often the joint is opened (Fig. 52). The tendency of this joint to become fusiform and chronically stiff after injury is not so marked as in the case of the proximal interphalangeal joint. A knuckle joint opened through sharp contact with an adversary's teeth is a serious matter. The circumstances in which the wound was acquired often provoke a furtive reticence until an acute septic arthritis of the joint develops. In spite of antibiotic treatment such a complication is liable to lead to permanent stiffness of the knuckle joint.

Treatment. If the joint is opened the capsule should, if possible, be sutured separately with a few very fine steel stitches. A bite wound, however, is almost certain to suppurate and only a delayed primary suture is permitted The division between the capsule and the tendon is easily defined. The tendon edges are approximated by two or three interrupted fine steel sutures which do not require removal. In this situation the finger has to be supported by a splint after suture with the tendon relaxed. It is wise to apply a palmar plaster splint holding the finger almost fully extended at the metacarpo-phalangeal joint. If the suture is precarious it is necessary in the first instance to extend the splint to the tip of the finger. This can be shortened at the end of two weeks when the stitches are removed, so that only the proximal phalanx is held extended. The liberty permitted to the terminal two joints in the finger does not increase the tension on the suture line very much. It should be perfectly able to withstand this extra tension two weeks after the suture. The knuckle should be supported from falling into flexion and so stretching the suture for two more weeks making, in all, four weeks protection after suture. The metacarpo-phalangeal joint is liable to be stiff after injury and splintage so that the routine form of physiotherapy may be necessary afterwards to restore movement.

A sufficient inspection must be made following injury at this site, because the lumbrical and interosseous insertions into the extensor aponeurosis may also have been divided. If one side of the aponeurosis has been divided, the other remaining intact, it is possible that the extensor tendon will dislocate, on use, from the eminence of the knuckle and slip to one side. This small handicap can be prevented if both sides of the knuckle are inspected and any damage rectified. In the instances where it is considered unwise to enlarge the original laceration inspection may not be possible until later suture.

Division of the Extensor Tendons on the Dorsum of the Hand

Injuries that occur on the back of the hand vary from a simple incision made with a kitchen knife to an injury caused by machinery which not only lacerates the skin but divides tendons and fractures metacarpals.

Should the injury be severe with great damage and loss of skin, together with fracturing of metacarpals, it is inappropriate to suture tendons in

the first instance. On such occasions it is correct to replace skin loss, if necessary, by immediate grafting.

A typical wound is one in which the skin is simply incised or lacerated on the dorsum of the hand, with or without a flap being lifted and with

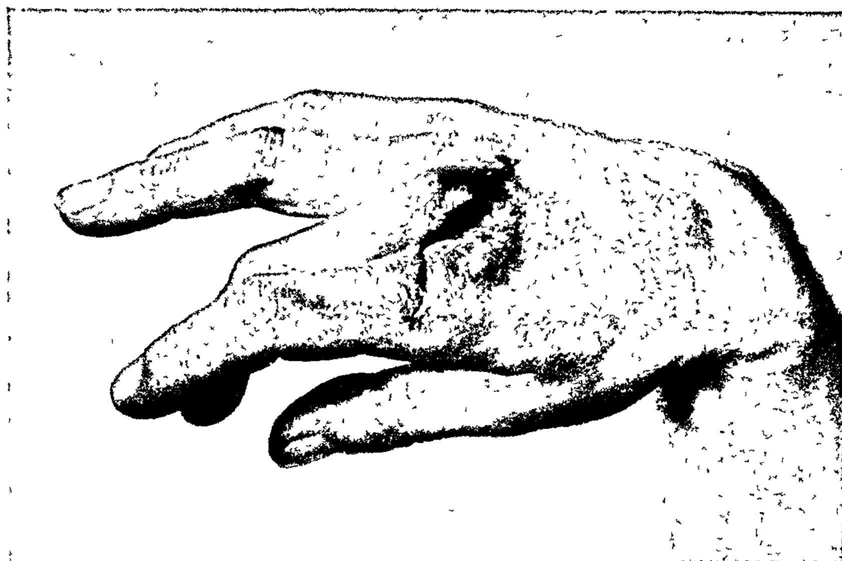


FIG 53 (*a*). The dropped medius denotes division of the extensor tendon. The joint was not opened.

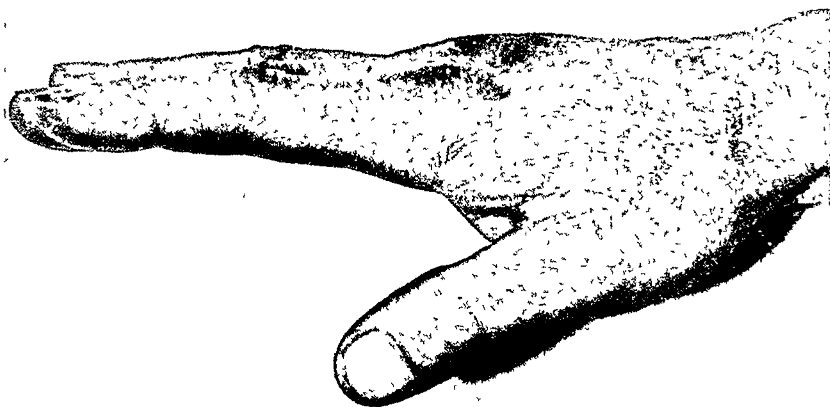


FIG 53 (*b*) Immediate tendon suture was done.

damage to one or more of the tendons (Fig. 53). The extent of the tendon damage will be immediately obvious, even in an incised wound. The patient indicates that the fingers are dropped at the metacarpo-phalangeal joints. It is a characteristic attitude and cannot be missed if looked for. A division of an extensor of the thumb, particularly the extensor brevis,

may be much more difficult to recognize and it is quite excusable that this tendon damage could be overlooked in the first instance.

Treatment. If the wound looks favourable, the skin damage is slight and there is reason to believe that contamination is mild, the tendon ends should be sutured at the time of primary surgery. Small stitches of fine stainless steel wire are used if the division is oblique or irregular. A transverse division of tendon requires a suture which obtains a firm hold by passing in a basket-like manner through at least ½ inch of tendon on either side of the division. It is usually more satisfactory to use the withdrawable technique if more than one tendon has been damaged. Following either type of suture the skin is restored and the tendon is relieved from strain by a suitable palmar plaster splint to hold the wrist and the metacarpo-phalangeal joints extended.

An endeavour should be made at tendon suture to identify the tendons accurately. If both tendons to the index or little finger have been divided, the corresponding tendons should be sewn to each other. The extensor proprius permits independent extension of the index finger and similarly the extensor quinti digiti independently controls extension of the minimus.

Delayed Primary Suture. There is no essential difference in the technique of a primary and a delayed primary suture. The occasion for delayed primary suture is frequent, because often the presence of the tendon injury is not suspected or the patient does not seek advice because of the trivial skin wound. Often the tendon is not touched at the time of primary surgery. A delayed primary suture may have all the advantages of planned surgery, whereby a flap is raised so that the tendon and skin sutures do not come in contact. During the interval between primary skin suture or natural healing and delayed primary suture, any latent infection has the opportunity of resolving so that the chances of infection following tendon surgery are lessened considerably.

Secondary Tendon Suture in all Areas

Whereas secondary suture in an instance of division of the flexor tendons is not an altogether hopeful procedure, secondary suture of tendons divided on the back of a hand is an effective operation and functionally satisfactory. It is not profitable to classify tendon suture on the back of the fingers too minutely. The tendon is sutured at the earliest feasible moment but the timing is controlled not only by circumstances relating to the wound but also by the state of the finger joints. Any form of suture may be vetoed by a stiff joint. A joint remaining partially stiff may defer suture or grafting indefinitely. If, happily, the finger remains mobile at the proximal interphalangeal joint, reparative surgery may be undertaken. This does not often take the form of secondary suture. After a delay amounting to weeks or months, repair by free grafting is more usual.

When exposing the tendons on the back of the hand or wrist, a flap incision is admirable because there is no possibility of the tendon suture

line becoming adherent to the skin wound. The tendon ends are exposed and they are easily identified by a knob of fibrous tissue which is present at either end. The ends may, in fact, be in continuity. The knob consists of proliferated tendon and areolar tissue; it is an abortive effort at spontaneous repair. After the knob is detached from its local adherence the tendon can be mobilized, for a distance, in either direction. The tension is relaxed by dorsiflexion at the metacarpo-phalangeal joint and the wrist and usually the ends will come into easy contact after excision of the fibrous nodules.

In this instance suture of the tendon by the withdrawable technique is the method of choice. The tension at the time of secondary suture will be greater than that met with at a primary or delayed primary suture. A good hold has to be obtained on the tendon. It is possible by other methods to obtain a similar hold, leaving wire in place, but this is not altogether satisfactory as the tension is fairly great. Although the withdrawable suture technique is more trouble to use, it is safer because the proximal tendon end is sutured to the skin, short-circuiting the suture line. The extensor tendons at the time of secondary suture are likely to be attenuated and partially degenerate and they do not hold sutures very well. When the skin has been sutured, a splint is applied to hold the metacarpo-phalangeal joint extended. In this instance it is advisable to hold the finger in the partially extended position for three weeks from the suture. Following removal of the splint the finger must be protected from forcible palmar flexion for a further three or four weeks.

Repair of Tendon Defects in all Areas by Grafting

Defects in extensor tendons, like those of flexor tendons, can be made good by free tendon grafting. The ultimate necessity for a graft is usually recognized at primary surgery. For instance, a large flap of skin may be elevated from the dorsum of the hand or wrist and it may be seen that the tendons have been irreparably damaged or even carried away. Sometimes tendons are excised at first surgery because the damage has been too great, or subsequently they may have to be removed in the course of treatment for suppuration. If a large flap has been lifted from the dorsum of the finger, it will be known at the time of primary surgery if there is a defect in the extensor tendon. When the patient has overcome the effects of the injury and movement has been restored in the corresponding joints attempts at tendon restoration may be made (Fig. 54).

When the previously injured area is exposed by means of a correctly planned incision or flap, it will be found that the proximal end of the tendon has not retracted very much and that it is adherent to the surrounding tissue. Similarly, the end of the distal part is also adherent. The paratendon between the tendon ends seems to proliferate in an abortive attempt to repair the gap. The fibrosis binding the tendon ends to the surrounding tissue is excised; the tendon itself is freed and mobilized in the paratendon for about an inch from either end. The gap is measured.

Three sources of grafts may be considered. The palmaris tendon is a good all-purpose graft, easily obtained and of adequate length. Where several extensor tendons have been destroyed another source is necessary. The extensor longus digitorum can provide several slips to replace lost extensor communis tendons. The length of the tendon has to be exposed so that the surrounding paratendon can also be removed, thus preserving the gliding mechanism. It is, of course, possible to place a tendon graft

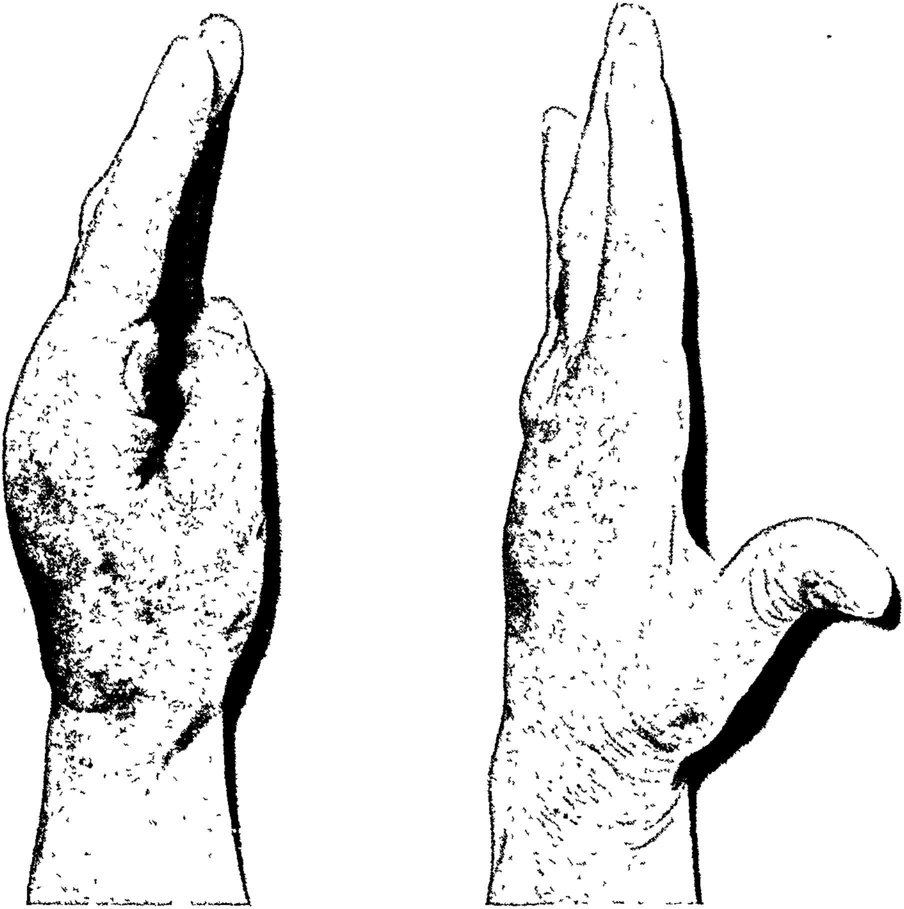


FIG. 54. The extensor longus and abductor longus tendons had been destroyed A palmaris graft provided an effective substitute.

under a thick dermatome skin graft, provided sufficient time has elapsed to permit mobility to develop.

The graft is best inserted by splitting the host tendon horizontally, in the alligator jaw manner, placing the free graft into it and sewing the alligator jaws firmly together to grasp the end of the graft. The finger is extended at the metacarpo-phalangeal joint and at the interphalangeal joints, with the wrist also extended. The other end of the graft is sutured into the host tendon in a similar manner under a moderate amount of tension. Even in recent injuries it is necessary to graft under tension. In an older injury the tension must be greater as the muscle will be reluctant to elongate and will only do so when it is used functionally and

stretched. When the second suture line is completed the skin is replaced and sutured. The hand, encased in pressure dressings, is immobilized with the wrist and metacarpo-phalangeal joints extended. If the tendon loss is on the dorsum of the hand it is unnecessary to immobilize the interphalangeal joints. They may be left entirely free. Tendon grafting

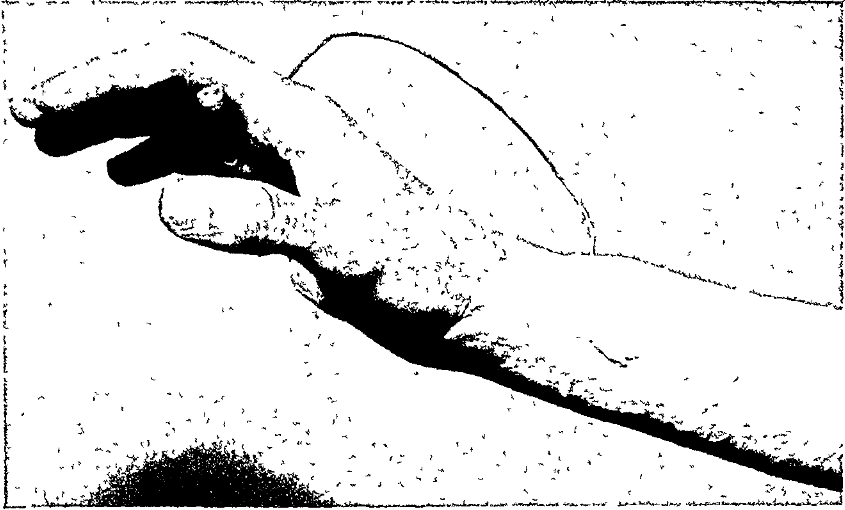




FIG. 55. The post-operative Brian Thomas is more readily made by the surgeon than by the instrument maker.

on the back of the finger, however, must be followed by extension of the finger joints. The combination of fixation and compression is maintained for three weeks. The stitches are then removed and the extension of the metacarpo-phalangeal joints is now maintained by a splint of the Brian Thomas type (Fig. 55). This splint permits active flexion of the fingers and supplements the weak but strengthening effort of the grafted tendon This Brian Thomas splint should be worn and used continually, until it is

evident that the graft is acting well and strongly and the patient is able actively to extend the finger against some resistance. The splint may be abandoned at six or eight weeks from the operation.

At the Wrist

Tendon divisions at this site are only mentioned separately because of the posterior carpal tendon sheath. The finger and thumb extensors lie in synovial tendon sheaths at the back of the wrist, because of the change of direction that takes place at this point. The synovial sheaths lie in grooves on the back of the radius and ulna, roofed over by the posterior annular ligament.

The particular arrangement of the tendons in the grooves does not matter to the surgeon very much. The important point to be realized is that if a suture line comes to lie in one of the synovial tunnels at the back of the wrist, no attempt at reconstitution of the posterior carpal ligament should be made. The suture line must be left free, otherwise it will become adherent. If the tendon repair involves use of a free tendon graft, it is wise for the graft to be long enough to traverse the area of sheath permitting the suture lines to be in paratendon territory. Naturally, after any repair in this area the suture line is relaxed by splintage of the wrist in dorsiflexion for at least three weeks.

TENDON DEGENERATIONS

Ruptured Extensor Longus Pollicis

Typically this episode occurs in middle-aged women. During the course of normal action, such as wringing clothes or playing the piano, a sudden pain is felt at the base of the thumb, extending up the back of the forearm. The thumb becomes useless and remains adducted across the palm. Movement of the base of the thumb rapidly returns and then it becomes evident that there is loss of active extension of the terminal joint. The tendon rupture often has an association with relatively trivial injury. The association with injury to the wrist is unmistakable, though bony deformity is not always present. The interval between injury and rupture is usually a few weeks, between two and eight. A condition described as drummer-boy's paralysis was well known in the army of the Kaiser. The drummer boy marches along, beating his kettledrum with martial vigour when suddenly, to his lasting shame, one of the drumsticks flies out of his hand. The extensor longus pollicis has ruptured. At operation it is found that the tendon is frayed in the region of Lister's tubercle. Presumably repeated movement of the tendon in the tunnel, while under tension, starts the process of attrition leading to rupture.

Diagnosis. To the doctor the diagnosis is simple. The entity is known and well recognized but sometimes it can be confusing should it

happen whilst the wrist is still in plaster for the antecedent Colles' fracture. There is no reasonable differential diagnosis, though occasionally obscure nerve lesions are diagnosed by the ignorant.

Pathology. The facts are these: the extensor longus pollicis tendon ruptures in its course and the site of the rupture is that part of the tendon which lies in the fibrous tunnel at the level of Lister's tubercle. At this point the tendon is devoid of paratendon. The tendon, both proximal and distal to Lister's tubercle, is surrounded by paratendon. The excursion of the tendon at this level is slightly over an inch. Although injury is a frequent curtain-raiser to rupture, bony deformity of the tunnel is not an essential ingredient. Sometimes there is no history of injury at all, though on all occasions there is a history of often repeated use. If the tendon end is examined histologically immediately after rupture it can be seen that the tendon was degenerate prior to the rupture. In those instances associated with injury it must be assumed that the injury precipitated the degeneration.

Treatment. Because the essential pathology of the condition is one of degeneration, end-to-end suture is rather difficult. The result is liable to be capricious; all the more so because the suture line comes to lie in a fibrous tunnel, to which it will invariably become adherent. Therefore restoration of function, after rupture of this tendon, is undertaken by other means. A tendon transfer is the method of choice, whereby a different muscle is connected to the distal end of the ruptured tendon, thereby avoiding the likelihood of adherence and making the suture easier. A tendon transfer is more likely to be effective if the new motor has roughly the same excursion as the original one and if it does not have to work through an angle.

In order to perform this operation a tourniquet is applied above the elbow and a curved incision is made to expose the extensor proprius indicis just distal to the posterior carpal ligament and at the same time expose the tendon of the extensor longus pollicis. A small incision is made, just proximal to the index knuckle, and the tendon of the extensor proprius indicis, the ulnar one of the two, is identified and divided. Its proximal part is seen in the curved incision and drawn out of the wound. The tendon is mobilized sufficiently and is brought in contact with the distal part of the extensor longus pollicis. At this stage the wrist is dorsiflexed and the thumb is held extended by an assistant. The suture is made by weaving the proprius indicis tendon back and forth through the distal part of the extensor pollicis tendon. The tension is dictated by experience and it is better to incline toward more tension than less. Five or six fine stainless steel wire sutures are used to fix both tendons together and the ends are trimmed. The skin is sutured and after a pressure dressing has been applied, the hand is immobilized with the wrist and thumb in the extended position. This is maintained for three weeks; at the end of which time the dressings and the stitches are removed. A cock-up splint is used for a further three weeks. The results

of this tendon transfer are very good and effective and, strange to relate, there seems to be no disability detectable in the index finger.

The other tendon transfer which is popular for this condition is to suture the extensor brevis to the distal part of the extensor longus pollicis (Fig. 56). At a point over the metacarpal these two tendons lie very close together. There is little disturbance necessary, therefore, and no added angle through which the tendon must work. The extensor brevis pollicis does not have an excursion as great as the extensor longus and the tendon itself is rather frail and thin, but the results, in spite of these theoretical disadvantages, are good. A flap is made to expose the dorsal aspect of the first metacarpal and the two tendons are easily identified. The distal



FIG. 56 (*a*). The extensor longus pollicis has been ruptured

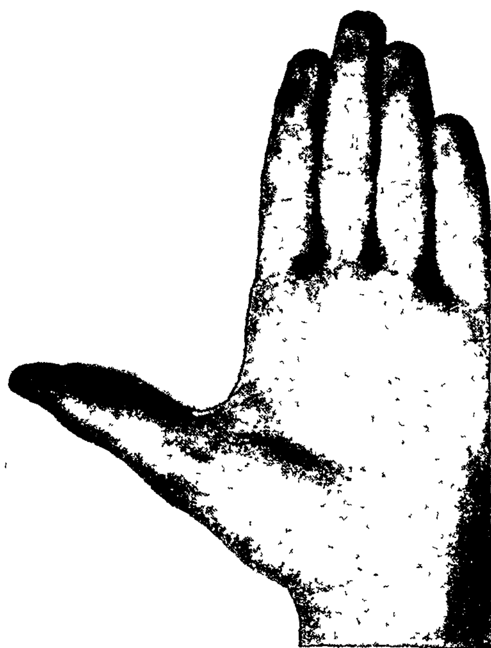


FIG. 56 (*b*). After transfer of the extensor brevis tendon into the longus mobility is restored.

end of the extensor longus tendon is mobilized and threaded twice or thrice through the extensor brevis. With the wrist held extended the extensor longus tendon is pulled firmly proximally and the extensor brevis is pulled firmly distally and the two tendons are sewn together by fine interrupted stainless steel wire stitches. The free proximal end of the longus tendon is excised, the skin is sutured and the thumb is held extended by a plaster splint for three weeks. Results from this operation are equally as good as those using the extensor proprius indicis.

Rupture of other Tendons

Both flexors and extensors of the fingers are very apt to rupture during the evolution of rheumatoid polyarthritis. Frequently the episode of rupture which occurs during a normal action passes unnoticed. Rup-

tures of the flexor profundus and to a lesser extent of the sublimis can be considered as part of the disability of polyarthritis. It accounts for the typical straight finger deformity which accompanies ulnar deviation. Rupture of an extensor is more of a bother to the patient as it occurs over the dorsum of the hand and causes a dropped finger.

Treatment. Rupture of a flexor tendon in polyarthritis does not merit suture. The disability is not sufficiently great, and the chances of stiffening the finger are greater.

Rupture of a finger extensor on the back of the hand is a different matter. It should be sutured. The Bunnell withdrawable wire suture is used to short circuit the insertion of the extensor muscle. This allows the finger to be passively mobile, thus preventing stiffness from developing during the three weeks of restraint. The results are usually very good.

The de Quervain Syndrome

This condition is included, although the pathology of the disability is not strictly sited in the hand. Symptoms, however, are felt in the hand, especially in the thumb or radial aspect of the wrist. It is a disability of middle age and usually of women engaged in household duties. The classical de Quervain syndrome is a tenovaginitis of the long abductor of the thumb and unless treated it is apt to be indolent. A similar condition sometimes is met with in young masseuses and nurses in training. In these instances disability is transitory. This variant really consists of a tenosynovitis where the tendons lie in areolar tissue proximal to the fibrous sheath. A soft crepitus may be felt. There is such a strong capacity to get well that continued use cannot prevent it. Often there is a history of injury but this is probably to be discounted, because all patients search in their minds for some cause to explain their disability.

Diagnosis. Patients with the de Quervain syndrome complain of pain and disability which they refer to the radial side of the wrist and the thumb. The diagnosis is made by objective examination rather than on the history, which is always a little vague. It is found that there is tenderness and swelling on the radial styloid, extending proximally and dorsally. The swelling lies over the course of the short extensor and abductor of the thumb. In addition pain is complained of during active and resisted extension of the thumb.

Pathology. The condition is a tenovaginitis and at operation it is found that the fibrous sheath of the extensor ossis metacarpi pollicis (abductor longus) and the extensor brevis pollicis is thickened. This thickening is not trivial; it may exceed an eighth of an inch in depth and it narrows the tunnel. It is obvious from the histological examination that the disability is due to difficulty in moving the tendons through their thickened sheaths. The tendons themselves are normal. Only the sheaths are thickened. The collagen fibres are degenerate ; the nuclei barely take up strain. The degenerate areas are replaced by new fibrous tissue of irregular disposition and hyperplastic form.

Treatment. Spontaneous resolution and cure is not unknown and if the patient's complaints are moderate, and if the length of history is short, the appropriate treatment is expectant, together with an innocent liniment as a placebo. Some patients will be spontaneously cured.

Those patients who seek a cure on demand are best treated by incision of the tendon sheath where it is thickened. Other treatment is hardly worth considering. Treatment by radiant heat, by local transverse frictions or plaster splintage, is advocated from time to time by those who have no other treatment to advocate and it consists in occupying the patient's attention until nature effects a spontaneous cure. The surgeon can instantly cure the condition by incision of the sheath. The technique is simple; the anæsthetic is a matter of availability and fashion. Probably the easiest way is to use pentothal but if a general anæsthetic is considered a little formal for trivial surgery, a brachial plexus block may be used.

Only a bloodless field can give an adequate vision. A tourniquet is placed above the elbow; the skin is prepared for surgery in the usual manner. An incision is made at the site of the radial styloid, along the course of the short extensor and abductor tendons of the thumb. The fibrous tendon sheaths are identified and that for the extensor ossis metacarpi pollicis and for the extensor brevis pollicis are incised throughout their length so that the tendons are completely liberated. The skin is sutured with fine wire and after crepe bandage compression the tourniquet is released. When the patient awakens from the operation it will be evident on first movements of the thumb that she has been cured. No after-treatment or rehabilitation is necessary. The stitches are removed in ten days and thereafter the patient will consider herself normal.

Trigger or Snapping Finger

This is a characteristic condition which is rarely misdiagnosed. It occurs most frequently in middle-aged women, who state that the ring or middle finger seems to, or actually does, become caught in the flexed position. In addition to the disablement of function there is tenderness on the palmar surface of the metacarpo-phalangeal joint of the affected finger. The index or little fingers are rarely involved but not infrequently the thumb is affected.

Diagnosis. The diagnosis is simple and should never be in doubt (Fig. 57). At first there is a sense of painful grating on movement but with time this evolves into the typical clicking syndrome. If the patient complains of disability in use of the finger and there is tenderness in the palm at the level of the transverse crease, the condition is identified if the finger in other respects is normal. Similarly a complaint of disability in the thumb, with local tenderness over the metacarpo-phalangeal joint, makes the diagnosis equally obvious. When the condition has evolved the patient will be able to demonstrate that the finger remains flexed on attempting to extend it after clenching the hand. An attempt to release

this finger by force will be accompanied by a sudden painful snap as the finger springs into the extended position. The finger itself and the interphalangeal joints are normal. It is to be noted that both interphalangeal joints are held flexed, denoting involvement of the profundus tendon. With the finger straight, a point of tenderness on the palmar aspect of the proximal phalanx will frequently be found.

Pathology. The tender spot in the distal part of the palm marks the entrance of the fibrous digital sheath. The disability is caused by localized swelling, usually in the flexor profundus but occasionally in the

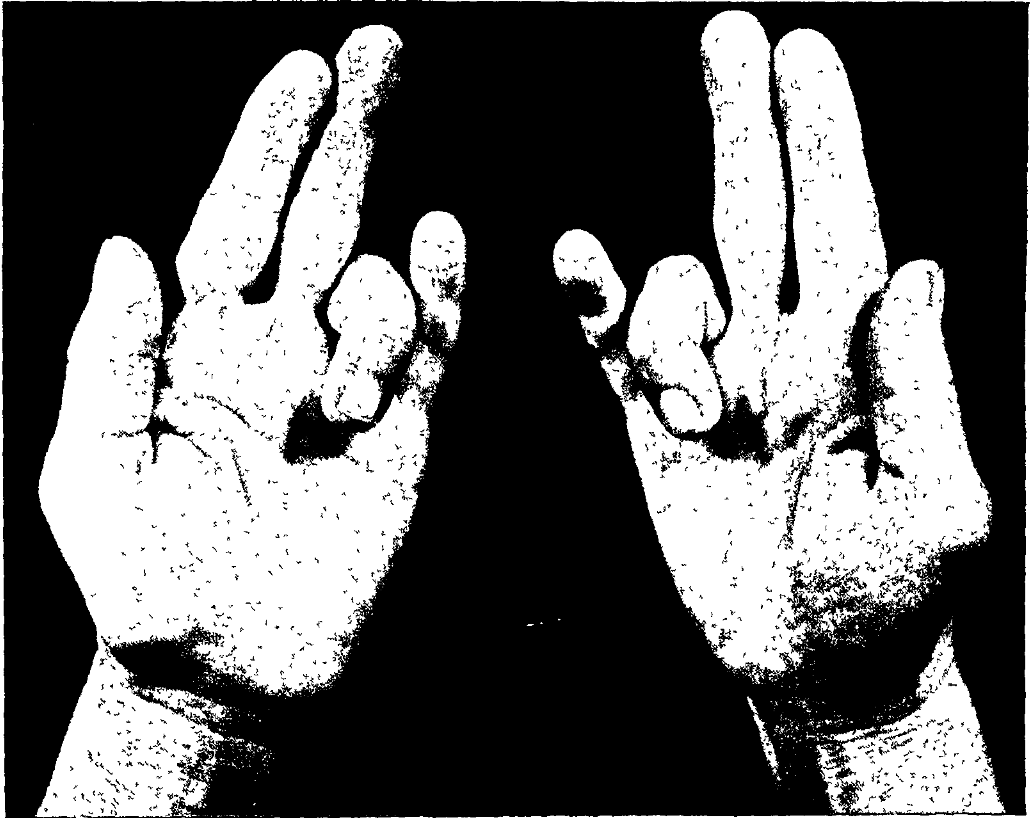


FIG. 57. The diagnosis is never in doubt if the fingers click straight from this position.

flexor sublimis tendon. When the finger is actively flexed the lump emerges from the digital sheath and lies in the palm. On straightening the finger it is difficult for the lump to enter the digital sheath, the entrance of which is narrower than the tunnel itself. Straightness is achieved by actively pulling the lump into the sheath and this is accompanied by a momentary painful snap.

The lump consists of degeneration within the substance of the tendon. It seems that the cause of the localized degeneration is ischæmia. The portion affected is in the middle of that part of the tendon that has a poor blood supply anyway. For a length of nearly 4 inches the profundus is

surrounded neither by paratendon nor mesotendon. The only external source of blood supply is derived from a vinculum at the level of the proximal interphalangeal joint. Impoverished blood supply may be the cause of the degeneration. The ætiology is not clearly determined yet. Occasionally, when the swelling is exposed, the degenerate medulla of the tendon is actively extruded from within when the tension is relieved. The naked eye appearance of this extruded material from the profundus tendon is very similar in appearance to that which is seen in an instance of degenerative supraspinatus tendinitis.

Treatment. The early stages, in which the tendon is tender and painful in its movement, may evolve to a trigger finger or may resolve spontaneously with time. Presumably in the latter case the swelling decreases and free action of the tendon is thereby regained. If, however, snapping of the tendon does take place and a patient wishes to be cured, incision of the entrance of the digital sheath in the palm will promise immediate and lasting cure. There is no place for physiotherapy in this condition. The operation may be deferred with advantage because spontaneous cure is known to occur.

If it is decided to cure the patient, a suitable anæsthetic is chosen and a tourniquet is applied. A transverse incision 1 inch long is made in the distal palmar crease and the appropriate tendon sheath identified. The proximal part of the sheath is incised for half an inch. The tendon is now able freely and comfortably to glide. The wound is sutured and the patient awakens from the anæsthetic aware that she is cured. The stitches are removed at the appropriate time and no after-treatment is necessary.

When the thumb is involved the history is similar, the pathology is the same and the cure is equally simple. Through a small transverse incision at the level of the metacarpo-phalangeal joint of the thumb the tendon sheath is exposed. It is divided for ¾ inch, about the level of the metacarpo-phalangeal joint. The skin is sutured and the patient is delighted.

Congenital Snapping Thumb

This is a curious condition which does not seem to fit with the other examples of snapping finger. The facts are these: a few hours or days after birth it is noticed that the baby keeps one or both thumbs fully flexed at the interphalangeal joint. It is obvious from the appearance that it is a normal thumb which is stuck flexed and not a congenital deformity of the thumb. On forcing extension of the thumb it suddenly snaps straight. This is accompanied by a bellow of surprise and unless the joint is held straight it is almost instantly drawn down again. Mother will be difficult to convince. On palpation it seems that thickening is to be felt at the metacarpo-phalangeal joint.

Treatment. It is believed by many that normal function is spontaneously restored. At all events it is correct in the first instance to advise

no treatment after explaining that a spontaneous cure is likely. Sometimes the flexed condition remains through infancy, even up to the age of ten. There are remissions, however, and from time to time the thumb functions normally, only to relapse into its flexed state for no obvious reason. At any time after three years old, if the parent is tired of the deformity, it can easily and instantly be cured by a procedure similar to that used in the adult.

CHAPTER 6

AFTER-TREATMENT AND COMPLICATIONS OF REPARATIVE TENDON SURGERY

AFTER-TREATMENT OF TENDON REPAIRS

Routine Treatment

The immediate concern following surgery is to prevent hæmatoma formation, which may be the prelude to infection and always the prelude to stiffness. Accurate skin suture is necessary for rapid and clean healing. Activist surgeons understandably wish to begin tendon movement as soon as possible. This not only demonstrates active movement of the finger to the patient, and so encourages him, but the surgeon himself has a feeling that if the tendon can be got moving early it will be fairly simple to retain the motion. Others believe in a combination of compression and stillness to reduce hæmatoma formation to a minimum, thereby discouraging adhesions which subsequently limit tendon gliding.

The important school of hand surgeons in Chicago, led by Sumner Koch, believe with conviction that the combination of rest and compression is essential to secure good function following tendon surgery. When tendon ends are brought together in co-aptation they of themselves, on account of poor blood supply, have little power of healing. The suture line has, as it were, to call on the surrounding tissue; in fact a mass of tissue is formed similar in effect to ensheathing callus. The tissue surrounding the suture line becomes hyperæmic and the local hæmatoma organizes into granulation tissue with fibroblasts laid down in an irregular manner. At this stage, two or three weeks after suture, the immediate area surrounding the repair is coalesced into an organizing mass of granulation tissue which is vascular. The fibroblasts are scattered irregularly, lying in all positions. At three weeks it is evident that the tendon ends are stuck together by fibrous tissue. From this time onwards the proliferating fibroblasts assume an adult form and arrange themselves in parallel order, changing gradually to adult collagen tissue. The tendon ends are now adherent by intermediate callus, which is to remain the true bond of union. At five weeks the local hyperæmia has settled and the intermediate collagen callus is becoming adult in form, blending with the normal histology of the tendon. The surrounding fibrous reaction lessens in bulk and becomes absorbed. The similarity with callus is obvious. Ultimately the tendon, whether there has been a simple suture or a tendon graft, assumes a normal anatomical appearance, though naturally there are some remaining adhesions between the suture line and the immediate surroundings.

The preceding brief account of the physiology of tendon union will

The splint and bandages are removed after three weeks and the stitches are taken out. The hand at this time may be tender and of little use and it should be protected by a light removable dressing. An ordinary cotton glove is adequate. During the fourth week the patient restores movement to the other fingers, the wrist and the elbow. The hand is bathed several times daily so that at the beginning of the fifth week it is in a condition fit to benefit from re-education. After a flexor tendon repair the posturing splint may be abandoned at the end of the third week. In the case of the extensors, however, including the thumb, it is wise to protect the suture line from being stretched for six weeks. A lively splint, allowing movement but preventing continued stretching by gravity, is ideal and may be used from the fourth week onwards (Fig. 55).

A physiotherapy department is not necessary. An interested physiotherapist is useful for treatment but not essential. Re-education is necessary and the principles of hand function and of cerebral patterns must be understood.

Special Treatment

Flexors. Following the initial injury the patient is unable to carry out certain active movements. The pattern of control of these movements is lost to the cerebral cortex because the patient is only capable of doing some modified motion. For example, on asking a patient to clench the fist when both flexor tendons to a finger have been cut over the proximal phalanx, he will actively and fully flex the other three digits; whereas the affected digit will be flexed only at the metacarpo-phalangeal joint by the interosseous muscles. This is the best attempt that can be made at bending the finger; this effort at flexion, in itself, also extends the two interphalangeal joints. If this habit is permitted for several months, the pattern of movement on the cerebral cortex will become altered. The original pattern of movement, involving use of both flexor tendons synergically, is lost and is replaced by one of flexion of the metacarpo-phalangeal joint, combined with straightness of the interphalangeals, thus destroying the original conception of the motion. After surgery, whether it consists of suture of the profundus tendon or free grafting, this newly acquired pattern has to be destroyed otherwise the patient, if left to his own devices, will continue to bend the finger at the metacarpo-phalangeal joint, which, by straightening the interphalangeal joints, acts in direct opposition to the purpose of tendon surgery. In such an instance there seems to be a complete suppression of function of the operated tendon and until the pattern has been broken down there is no possibility of improvement.

A simple method of attempting to do this is by flexing the other digits fully into the palm, leaving the affected finger poking forward. The finger or thumb is then held extended at the metacarpo-phalangeal joint and passively and intermittently bent at the interphalangeal joints by the patient himself or the physiotherapist. The patient actively

attempts to flex the finger in unison with the passive bending. Alternatively, if the affected finger is fully mobile, all the fingers may be flexed into the palm and held there by the masseuse. Then the patient is enjoined actively to clench the fingers and thumb as strongly as possible. Training through communal or synergic action is often very effective in restoring the dominance of the deep flexor in finger bending.

Ultimately the pattern of movement is created by proprioceptive impulses passing from the finger and the patient is able to recognize the sensation of bending the interphalangeal joints. If these routines are carried out almost continually for several weeks the abnormal pattern of finger flexion may be so changed that the sutured or grafted tendon is exercised and rehabilitated. From this point the only obstacle to good function is adherence of the suture line or the tendon generally. The patient requires no special treatment except normal function, which function should largely consist of grasping objects of small size, such as the steering wheel of a car or the handle of the iron. A squash ball held in the pocket almost continuously and squeezed will help a great deal towards improving function, control and increasing tendon excursion. It must be realized, however. that active functional treatment of the finger is useless unless the dominance of the intrinsic muscles has been broken. Intrinsic dominance will not develop if the period between injury and operation is short and is not common if only the profundus tendon was divided. In the case of a simple division of the deep flexor, the sublimis remaining intact, the same technique applies after suture but the affected finger is held straight at both the metacarpo-phalangeal and at the proximal interphalangeal joint. The patient is enjoined and assisted to bend the distal joint. The time taken for movement to return after tendon suture or graft is extremely variable. Occasionally at the end of six or seven weeks free and encouraging movement is present. More frequently, however, movement is slow to develop and sometimes at the end of three or four months both patient and surgeon are discouraged because so little movement is present. In these instances hope should not be abandoned, because often improvement in function continues for up to a year following tendon surgery.

Checking Intrinsic Dominance

After a time, in spite of treatment, it may be obvious that the patient's pattern of pre-operative function is not altered and that other remedies will have to be taken. The situation is that intrinsic dominance has remained and that attempts to exercise the sutured or grafted tendon are neutralized or aborted by the over-active interosseous muscle which, though flexing the knuckle joint, prevents an inexperienced flexor tendon from bending the distal two joints.

At this stage the most effective method of restoring the normal pattern is by blocking the ulnar nerve. Three or 4 c.c. of 1% Xylocaine solution are injected one inch above the pisiform bone in the neighbour-

hood of the nerve, deep to the flexor carpi ulnaris. The needle does not have to touch the nerve though it should be in the vicinity. Xylocaine seems to have the power to diffuse. The ulnar nerve will be paralysed for half to three-quarters of an hour. When the block is complete intrinsic dominance cannot exist and the only way actively to flex the finger is by the long tendon. By a combination of encouragement and cajolery the patient should be able to re-establish the subjective feeling or pattern of profundus flexor action. If motion that should be present is slow to appear, faradic stimulation to the common flexor group may be needed to initiate control. Treatment must be continuous and repetitive in a resistant case. Synergism, rather than individual or purposeless movement, is to be encouraged. Ulnar nerve block is of special value in stupid patients who may not grasp the idea of treatment, or in those who have no manual dexterity. Once the knack of long flexor function has been established, though the excursion is slight, it will be retained and the patient then only has to increase the movement.

Sometimes little is achieved at first, and successive ulnar blocks are necessary. It is possible to interrupt conduction of the ulnar nerve by pressure. If a blood pressure cuff is applied round the region of the straight elbow and a small piece of rubber, the size of a wine bottle cork, is placed in the groove for the ulnar nerve, localized pressure is exerted on the nerve when the cuff is gently inflated without undue arterial constriction. The time taken for anæsthesia to develop in the area supplied by the nerve is noted. The pressure is left on for twice the time taken to achieve this loss of skin sensibility. The cuff is then removed and it will be found that the ulnar nerve has ceased to conduct. Treatment can continue without intrinsic dominance for a quarter of an hour or twenty minutes, until ulnar nerve function spontaneously restores itself. This performance can be repeated frequently until the pattern of function of the finger is fully imprinted on the cerebral cortex. Increasing tendon excursion is encouraged by function. Once the patient has some active control of the affected tendon he may return to work. A lorry driver's job is ideal for obvious reasons. It is not necessary to treat children because irreversible intrinsic dominance does not develop and the constant use of the hand, together with development, seems to restore normal function if it is mechanically capable of being restored.

Extensors. Sutured or grafted extensor tendons require continued safeguards when the immobilization and compression are removed three weeks from the operation. Gravity, as well as the natural posture of the hand, combine to stretch the bond of union. The tendons must be protected from the stretching force but continued immobilization is not required.

A spring splint, which always returns to a resting position of tendon relaxation, will permit intermittent movement. The splint should maintain mild dorsiflexion of the wrist and metacarpo-phalangeal joints. The fingers need not be held extended unless the tendon suture is distal to the knuckle joints.

A lively splint, of the Brian Thomas type, is most efficient for this purpose and should be used for three weeks. That is to say, up to six weeks in all from the date of operation.

COMPLICATIONS OF TENDON REPAIRS

Insufficient Excursion of Tendon

The most obvious and usual deficiency of reparative tendon surgery is due to insufficient excursion of the tendon. This applies as much to a sutured tendon as to a repair by free grafting. There are many causes for this imperfect result. Probably the commonest is adherence of the suture line. This is especially true where the suture line lies in the digital sheath and is applicable to a profundus suture in Zone 1, or Zone 2 after excision of the sublimis tendon. It is not the suture line alone which may be adherent. If there has been a delay of some weeks between injury and repair, the distal end of the tendon becomes partially adherent within the sheath. These adhesions, if they have only been present for a short time, are easily overcome and tendon movement is fully restored. Similar adhesions may reform during the time of immobility following suture.

The second obvious cause for insufficient movement of a finger after repair applies only in those instances where a free graft has been used. If too long a graft is inserted as a replacement for an adherent and functionless profundus tendon, it is likely that the outer range of finger movement may be possible but the inner range absent because the excursion of muscle is insufficient. This fact is very closely related to the excursion of the motor used with the free graft. If the motor is restricted in range, it is obvious that full finger motion cannot be restored, whatever length of graft is used.

(*a*) **Adherence of Tendon following Suture.** This is the major difficulty following suture of the profundus tendon and is apt to vitiate the result. To be certain that limited finger movement is due to tendon adherence, the surgeon must be satisfied that the arc of finger movement is the same with the wrist partly flexed as with it fully extended. During the course of normal after-treatment the profundus muscle is educated to function. If normal after-treatment fails to produce improvement and finger excursion remains deficient, the surgeon will have to decide whether a further attempt to improve gliding motion of the tendon by operation should be attempted. Tenolysis as a secondary procedure for adherence of the tendon or suture line has a good reputation. Often a tendon may be sutured in the knowledge that at a second stage tenolysis will be necessary. The tendon is encased in a tube of long fibred areolar tissue, normally found subcutaneously. The technique of this operation to improve tendon excursion is detailed on p. 33.

(*b*) **The Graft is too long.** If it is considered that finger movement is deficient because the flexor tendon graft is too long, this opinion can easily be verified. In such an instance the arc of movement of the finger

is increased in full dorsiflexion of the wrist. With the wrist in the neutral position the range is diminished. In the rare instances when the surgeon can convince himself that the arc of movement of the finger is increased by dorsiflexion of the wrist, it may be clear that the graft which has been inserted is too long. This is unusual. In such an instance the treatment is obvious. The tendon, at its insertion into the terminal phalanx, should be exposed and shortened. It is re-attached in the ordinary way. Removal of the redundant portion of graft should dispose of the deficiency.

(*c*) **Myostatic Contracture.** It may not be possible to know whether limited finger movement is due to insufficient excursion of muscle or to too long a graft. In both instances the clinical appearances are almost the same. Insufficient excursion of muscle is likely to be the cause of limited finger flexion if the tendon was divided many months before the repair by grafting. On division of a tendon the appropriate part of the muscle will shorten to less than its normal resting length because it is not pulled upon by the tone of the extensors. Remaining in this state for several months, the muscle undergoes a change known as myostatic contracture. This is irreversible. This change should not be confused with the fibrosis which may occur in a muscle which is disused. Myostatic contracture develops after some months and prevents lengthening. If, for instance, a primary suture has been made and the tendon subsequently becomes so adherent that it is necessary to replace it by a graft, it is found that myostatic contracture has not occurred and that the excursion of the muscle is normal. A certain amount of the shortness can be overcome by constant stretching, although truly the contracture is irreversible. It is important to adjust the length of the graft to the conditions. The graft should be proportionately shorter the greater the interval between tendon division and repair.

The deficiency of finger function due to myostatic contracture is best dealt with prophylactically and so avoided. Early suture is the best method of avoiding it. In an instance of extensive injury, suggesting delay in definitive suture, a rapid co-aptation of tendons is desirable. Length will be maintained and myostatic contracture thereby avoided (see p. 107).

Insufficiency of tendon excursion following repair may be complex in its origin. In general, however, it is probable that deficiency of grip, following a tendon graft for a division of long standing, is due to myostatic contracture; whereas limited finger movement, following an early tendon graft or a tendon suture, will most likely be due to adherence of tendon or suture line.

(*d*) **Massive Adherence of Graft.** Sometimes a free tendon graft results in total failure and no vestige of active motion is restored. Enquiry into the cause of this by re-exploration reveals massive death of the tendon graft. Throughout its length the graft is represented by a dense rod of fibrosis with no plane of cleavage between it and its host (Fig. 58). Presumably this is akin to total loss of a Wolf skin graft. For some reason



FIG. 58 (*a*). Three months previously a tendon graft was placed in the index The index contracted, became functionless, and was amputated.



FIG. 58 (*b*). The finger demonstrating the contraction of the tendon due to massive death.



FIG 58 (*c*) Division of tendon permitting the finger to be straightened easily

a blood supply is not re-established soon enough to save the tendon and not unnaturally it undergoes necrosis with its attendant reaction. The finger always becomes contracted, often to a grotesque degree. Attempts to straighten are met with a feeling that the deformity is irreparable. Nothing can be salvaged from this situation: usually the digit is better amputated. It is remarkable that it does not happen more often.

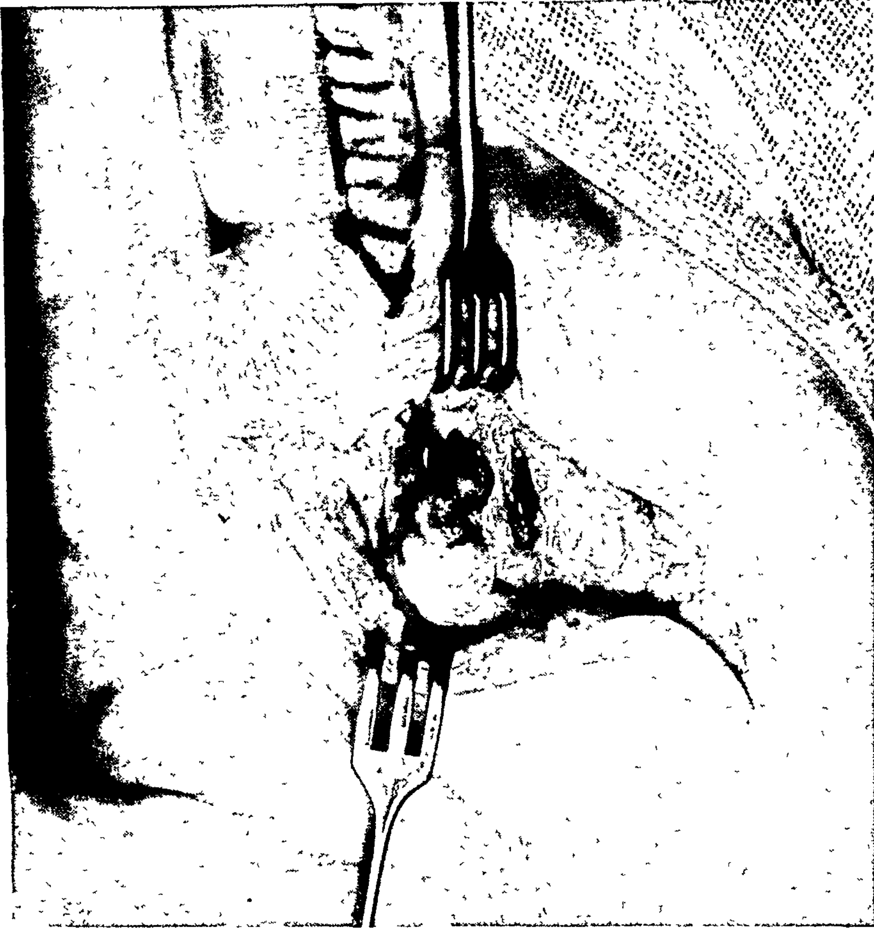


FIG 59 Both tendons were cut at the distal palmar crease In spite of a rope-like suture material the join has parted.
At this time the prognosis is worse than if the repair had never been attempted

The Broken Suture

Formerly, separation of the suture line was a fairly frequent occurrence, judging from the fact that surgeons seemed impelled to use strong suture material. This strong, and therefore bulky, material neutralized its good effect by provoking such a degree of local fibrosis that adherence of the suture line was bound to follow. The almost universal use of fine stainless steel wire, has made separation of the suture line unusual. Steel wire is very strong in proportion to its bulk. Similarly, steel wire being inert, provokes no adhesions. If a modern suture line breaks down it is most likely to be due to an error in technique (Fig. 59).

This accident does sometimes happen. It occurs during rehabilitation following operation. The patient is usually aware of the break and on examination after its occurrence it is found that there is no active flexion of the joint and that the finger has assumed its pre-operation posture. When a graft is used to restore tendon function, the surgeon should bear in mind that the material he uses is dead. It is, in fact, as dead as a free



FIG. 60 (*a*) Bow-stringing after a free tendon graft had been placed too superficially.



FIG. 60 (*b*). This does not imply deficient grasping

skin graft and union of this dead tissue to the living will be slow. Strain, therefore, must not be applied to the suture line in the early stages of liberation when rehabilitation is beginning. As mentioned previously, it is wise to relieve the suture line, whatever the type, from strain for at least four weeks. Movement should never be resisted, though free movement should not be encouraged. Not infrequently a free graft becomes detached from the terminal phalanx. If this is recognized early the surgeon

should not hesitate. A re-exploration of the tip of the finger should be undertaken in order to find the end of the graft, so that re-attachment to the terminal phalanx can be undertaken.

Bow-Stringing after Grafting

Bow-stringing of the tendon on active flexion is only possible when the normal restraining pulley arrangement has been destroyed. It is more likely, therefore, to occur in instances of repair by grafting than from simple suture. Generally a graft is more likely to be used if the finger has been extensively damaged. The disadvantages of bow-stringing are not great except that the excursion of the finger is reduced. When using the finger for pinching the deficiency is visible and real. On the other hand, during the action of grasping, the object being held keeps the tendon in its correct place so that the deficiency is neither visible nor troublesome (Fig. 60).

The Causes of Bow-Stringing. In instances where there has been extensive damage to the finger, possibly by infection, it is probable that the pulley is destroyed. Sometimes, if the pulley is normal at the time of reparative surgery it may have to be divided in order to effect the suture. If the pulley is not laid back or re-attached it is possible for the tendon to start forward afterwards, on active pinching movement. Sometimes when a palmaris graft is used it is, by mistake, led into the finger superficial to the pulley. If this is not recognized at the time of surgery, bow-stringing is inevitable.

Treatment. The fact that bow-stringing takes place is not an indication, of itself, for surgery. The effect of a pulley can, to some extent, be mimicked if the patient will wear a ring, similar to a wedding ring, over the proximal phalanx so that it will act as an external pulley. When it is decided to construct a pulley, this is simply done. A piece of tendon, about 3 inches long, is removed with paratendon, possibly the opposite palmaris tendon or a slip of the extensor longus digitorum in the foot. A lateral incision is made over the proximal phalanx and the tendon is threaded subcutaneously around the finger, superficial to the palmaris graft. The opposite side of the finger has also to be opened in order to manipulate the tendon. It is threaded back across the dorsum of the finger, deep to the extensor tendon. For this reason the pulley should not be placed too far proximal on the first phalanx, otherwise it will be difficult to get the pulley underneath the extensor cap. The ends of the pulley are sutured together in the original incision to complete continuity. The skin is closed in the ordinary way. A compression dressing is necessary for at least three weeks to ensure that the new pulley becomes effective. This operation is not done as frequently as might be supposed.

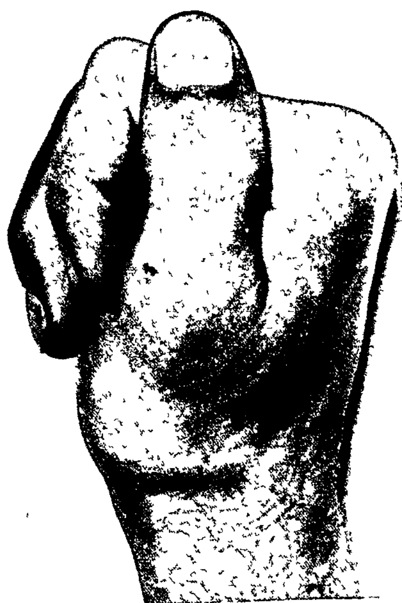
Fixed Flexion of the Interphalangeal Joints

This deformity, which is by no means rare and is perhaps more liable





FIG. 61 (*a*). Division of both tendons to medius permitting intrinsic flexion only.



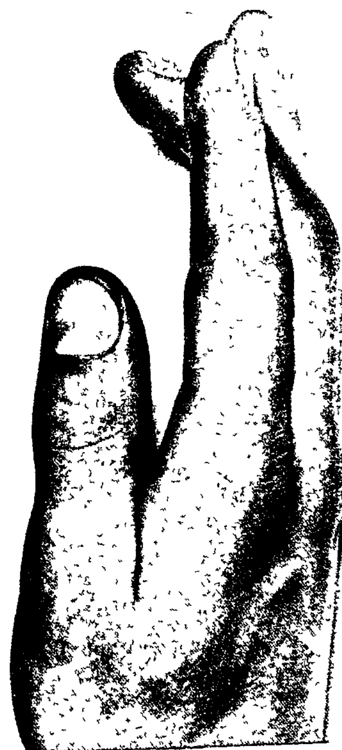


FIG 61 (*b*). After a palmaris graft, flexion has been restored but fixed flexion of the interphalangeal joints is an unwanted complication.

to affect the distal joint than the proximal, follows automatically if a joint has been opened either at the time of injury or at later surgery. It seems that the mere fact of dividing the volar ligament, ensures that a fixed flexion deformity will develop. If the joint is opened by the injury it will be recognized that the prognosis is poor and that deformity is probable. The distal or the proximal joint may be opened by the surgeon when the damaged and useless stumps of tendon are removed. Some care has to be exercised in separating the end of the profundus tendon from its normal adherence to the capsule of the tip joint. This should be done by a blunt instrument and not by cutting, as the two tissues are indistinguishable in appearance. Separation will be more difficult the longer the interval between injury and surgery. The proximal joint is liable to be opened whilst deep scarring is being removed from the finger or the sublimis tendon stump is being extracted (Fig. 61).

From time to time extreme examples of contracture are seen following tendon suture or graft. In these instances the contracture is probably a composite affair, partly joint contracture, partly tendon contracture, and so on.

Little can be done for this condition when it is fully established. Functionally, amputation is the best solution but there may be cosmetic objections against amputating a central ray in a woman. If an attempt is made to straighten the finger by surgery, it is probable that skin replacement by a free skin graft will be necessary, though a Z-plasty may be sufficient. In any case it will be unlikely for the finger to be functional. If the tendency to fixed flexion is recognized fairly early, in, say, the fourth or fifth week following tendon grafting, it can usually be prevented. Application of a spring splint, which will coax extension for several weeks or months, will prevent the deformity from becoming fully established and therefore incorrectable. The spring splint consists essentially of a piece of watch spring which is applied to the dorsum of the finger, in such a way that the natural tendency of the spring to coil is utilized gradually and quietly to extend the joints of the finger.

Hyperextension of the Proximal Interphalangeal Joint

This is a rare and rather obtuse complication which sometimes follows injury or tendon surgery in the finger. The proximal interphalangeal joint becomes hyperextended, so that when the palmaris graft or the solitary profundus tendon is contracted, the terminal joint only is flexed. The proximal joint remains locked in hyperextension, in such a way that the profundus tendon mechanically has no action on the joint (Fig. 62). If the joint, by knack or force, is bent, the profundus tendon can have its full play and flex the finger at both joints to the limit of tendon excursion. The exact cause for this deformity is not always clear. It has been thought by some to be due to removal of the sublimis tendon leaving too short a stump. The reverse is true. That is to say, if too long a stump of the sublimis tendon remains in the finger, adherence is apt to take

place, flexing the proximal joint in some small degree. The fact is that occasionally this curious anatomical feature does take place, and in a finger which has received a tendon graft, and it can well mar an otherwise good result. If hyperextension is troublesome and the patient is



(*a*)



(*b*)

FIG. 62.

(*a*) The proximal joint was locked in hyperextension and flexion is expended on the tip joint
(*b*) If the proximal joint is flexed the finger can be put to some use.

not able by some knack to overcome the disability, it is justifiable deliberately to scar the anterior capsule of the joint by opening it transversely, thereby ensuring fixed flexion. This complication is rare and it never is of great significance.

CHAPTER 7

INJURIES TO NERVES OF THE HAND

INJURIES to the nerves of the hand are divisible into three sites. There may be damage to one or both main nerve trunks at the wrist proximal to their ultimate divisions, as part of an extensive tendon cutting injury. Secondly, as the motor divisions of both nerves run a solitary course they may be divided without corresponding sensory loss. Both are necessary to satisfactory function of the hand and so they may assume major importance in reparative surgery. Finally, digital nerves may be divided causing sensory loss. This will render parts of the hand vulnerable to injury and impair usefulness.

The three different types of nerve injury are also represented in hand injuries. Anatomical division (neurotmesis) is the lesion that above all requires treatment. The complete lesion in continuity (axonotmesis), ordinarily caused by pressure or crushing, rarely results from hand injuries. Similarly the physiological lesion (neurapraxia) is rarely seen, except accompanying an incomplete anatomical division of the nerve trunk. That is to say, a patient who ultimately has a partial loss of conduction and a lateral neuroma may have had total loss of conduction for a short time after the trauma.

Nearly all nerve lesions of the hand and wrist are associated with wounding and so available for inspection. The difficulty in treatment of nerve damage in this site is usually related to the decision concerning excision of a neuroma and suture in a partial lesion.

THE MEDIAN NERVE

Though the main trunk of the median nerve is of limited extent in the hand, it is vulnerable to injury. Division of the median trunk is usually associated with tendon damage. An attempt at accurate assessment of nerve function should always be made before dealing with a wound in the wrist region through which the median nerve conceivably could have been damaged (Fig. 63). Although the tissues beneath the skin may have to be inspected at the time of primary surgery, an accurate clinical estimation of nerve function must be made before the patient is anæsthetized.

Early Diagnosis

In the initial stages, when the wound is being inspected in the Surgery or Receiving Room, many of the signs of an established median nerve paralysis are absent. Deformity and wasting will not have occurred. Nerve damage is detected clinically by sensory loss and motor inability.

At this stage the more important of the two is sensory loss. All that is needed to test the sensory function of the median nerve is a steel pin. The pin is stuck into the tip of the thumb, index or middle finger. If the patient feels a painful stimulus the nerve is at least in continuity. Complete loss of sensation to a sharp pin denotes either neurotmesis or axonotmesis. It is not essential at this stage to differentiate between qualities of sensation.

Primary Surgery. The hand is cleaned in the usual manner with a detergent and spirit. It is held elevated for a few minutes and a blood-



FIG. 63. A simple examination by a pin in the Receiving Room determined that the median nerve was intact. But for this, the surgeon would have messed about in the wound for some time and reached no conclusion as to the state of the nerve.

pressure cuff, placed above the elbow, is rapidly puffed up to 300 mm. of mercury. The wound is inspected to note any skin loss and to estimate any difficulty with skin cover and the surgeon will then be able to decide in what direction the wound may be enlarged in order to facilitate inspection of the median nerve and tendons. If the wound is considerably contused and obviously heavily contaminated, it may be unwise to extend the incision through uninjured tissue. In this instance nothing further remains to be done but to find the median nerve by retraction of the wound if previous clinical examination detected loss of sensation. A

quick look will establish whether the nerve is intact and undamaged, in continuity and damaged, or divided. It is not possible to be dogmatic about the lesion in continuity but an inspection at preliminary surgery will help in an accurate assessment of the nerve damage when weighed with the clinical findings as they evolve later. Direct nerve stimulation is of little use at this stage and is better avoided. Muscle end plate excitability continues for some days after axon division. The opportunities for confusion are obvious. The tendon damage can be rapidly assessed by flexing the fingers and counting the number of divided ends in the distal part of the wound.

The wound edges are trimmed, if necessary, and sutured as well as possible. If there is skin loss this should be made good by immediate free skin grafting. It is of capital importance to secure immediate skin cover, if only by a Thiersch skin dressing, to limit scarring and prevent infection. A deep and spreading fibrosis is apt to develop in the palmar and wrist regions which will make subsequent surgery difficult and efficient tendon repair almost impossible. The prognosis of an extensive open contusion at the wrist is bad.

If the initial wound is punctured or insufficient to allow of nerve inspection, it must be enlarged. The nerve must be seen if its conduction is abnormal so that its condition can be noted. If the nerve is partially divided with a wedge-shaped loss of tissue it may be appropriate, in a slightly contaminated wound, to close the gap by a single stitch. This may not, in itself, contribute to later nerve function in that it is not a nerve suture, but if the nerve edges are brought together the neurofibroma of repair will be of small extent. If it is necessary at a later time to resect the scar and suture the nerve, the amount of tissue to be sacrificed will be lessened. A nerve which is extensively lacerated and contused is better left alone. A stitch may be put through the damaged ends to hold them in reasonable apposition. This will prevent retraction and rotation and also form a marker for further surgery. The skin is sutured; at a later time definitive nerve surgery will be necessary.

A nerve that is cleanly divided, with glass or with a sharp instrument, evokes divided counsel amongst surgeons at the time of initial skin repair. Towards the end of the late war the word went round that primary nerve suture was not a desirable surgical procedure. This opinion was expressed by men of great experience, who found that in the main the results of a secondary nerve suture were better than those of primary. Because of this it has become the custom for surgeons not to suture a divided nerve at the time of primary skin suture. Simple co-aptation with a single stitch is permitted. Four to six weeks later the nerve is approached through a planned incision. It is exposed and the single conjoined neuroma or the two end bulbs are removed. An accurate and meticulous suture is performed under the best conditions. The technique of nerve surgery, whether primary or secondary, is similar and is dealt with on p. 44.

Diagnosis of the Established Lesion

The Complete Lesion. The established complete median nerve lesion may be recognized on sight. The alteration of posture of the thumb is characteristic. In addition to scars in the region of the wrist, the thenar eminence is flattened and the thumb itself is dropped back on a plane with the other digits. The thumb is flexed at the tip but active movement of the fingers and thumb will depend on the amount of tendon damage that occurred at the injury. Palpation of the thenar eminence confirms muscular wasting, particularly as the lateral margin of the first metacarpal shaft feels unduly prominent (Fig. 64*a*). The index and middle fingers are likely to be thin and atrophic and a little blue. The nail is unduly

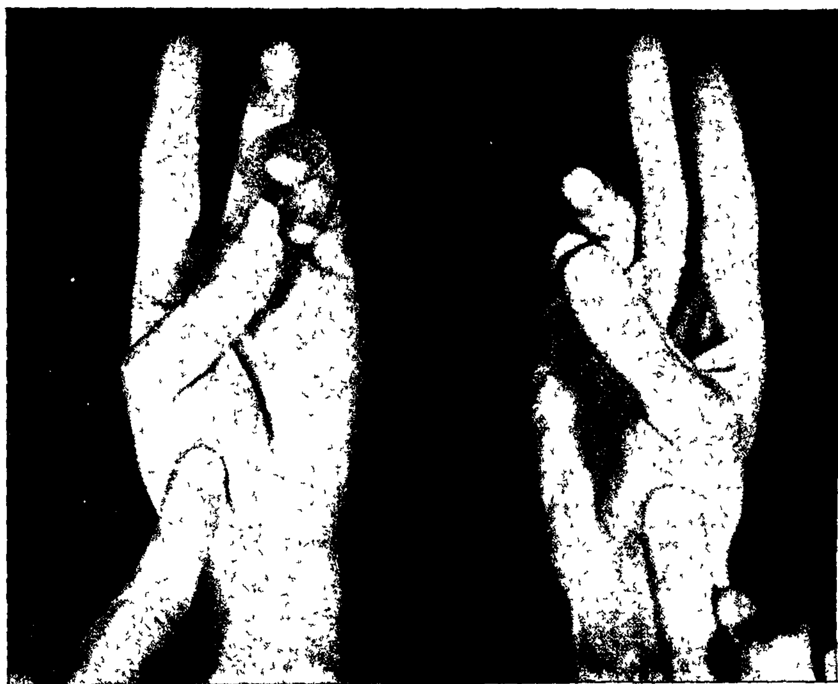


FIG. 64 (*a*). In a median nerve lesion the ridge on the lateral aspect of the first metacarpal is easily felt

curved and probably uncut, and the subungual tissue extends forward as though drawn out by the advancing nail. The trophic changes are often minor compared with those noted in a high lesion of the nerve.

Dryness of the skin supplied by the median nerve with normal moisture over the ulnar area, is characteristic and can be mimicked by nothing. Sensory testing should always be done. A sharp pin and a wisp of cotton-wool are all that are necessary. In a complete lesion there is absence of all skin sensibility to pin-prick and to cotton-wool over the area supplied by a median nerve. Joint position sense and deep sensibility are often retained. The motor investigation is carried out simply. The patient is asked to oppose the thumb to the little finger. The contact to be attempted is pad to pad rather than tip to tip. When this is

attempted with a median nerve lesion, only the tips of the thumb and the little finger can be brought in contact, and furthermore, the nail is in the vertical plane of adduction rather than in the horizontal plane of opposition (Fig. 64*b*). Opposition attempted in a complete lesion, when the deep head of the flexor brevis is innervated by the ulnar nerve, results in a trick movement that baffles the inexperienced. Opposition implies rotation of the first metacarpal on its long axis. Unless the bone rotates the movement is spurious.

The Partial Lesion. The diagnosis is more difficult in the case of a partial lesion. In such an instance the skin may not be dry; it may be as moist or even more moist than normal skin. There may be insensitivity to cotton-wool but appreciation to pin-prick, although this appreciation to pin-prick is not accurately localized and the sensation is abnormal in character. The patient can detect pressure on the skin but will be unable to decide whether it is sharp or blunt. On the motor side there may be evidence of voluntary activity in the thenar group. Electromyography will confirm this but it is of little assistance to the surgeon in helping him to make up his mind whether to explore the nerve or not.



FIG. 64 (*b*). Only the tip of the thumb and little finger can touch. The first metacarpal does not rotate.

The Irritative Lesion. From time to time instances are met with in which the dominant complaint after median nerve injury is of spontaneous pain in the area of cutaneous distribution. The spontaneous paræsthesiæ are painful in nature and pin-prick is felt as a poorly localized pain, spreading in distribution. Appreciation to cotton-wool is usually

absent. The hand looks atrophic, thin and moist and is covered with dirty epidermis. The thenar wasting is always considerable and although the nerve is in continuity, there is not much evidence of voluntary power.

The reason for the spontaneous pain is not known; no doubt it is related to causalgia, but at the moment the theories of the ætiology are not much better than speculation.

Treatment of the Established Median Nerve Lesion

The Complete Lesion. If it is known, from direct observation at primary surgery, that the nerve is divided, the surgeon has no doubts. The nerve is to be sutured as soon as possible after the advantageous



FIG. 65. Spontaneous co-aptation of end bulbs after a gun-shot wound.

delay of three or four weeks is passed. Suture may be further delayed unavoidably by reason of indifferent skin healing or florid and œdematous scarring in the front of the wrist. As in the case of tendon surgery, it is not wise to operate on a nerve whilst its surroundings are œdematous and infiltrated. Further, the nerve suture has also to fit in with the optimum programme of tendon surgery—if there is one. However, the aim remains: to suture the median nerve as soon as is surgically possible.

If the nerve was seen to be intact at first surgery, or if no information of its state is available, the surgeon may be perplexed. Neurapraxia, except as a transitory garnishing of a partial anatomical division, rarely occurs at the wrist and always recovers rapidly. Axonotmesis, whether due to crushing or traction (implying spontaneous improvement) is very rare at this site, and its theoretical possibility should not influence treat-

ment. It is reasonable to wait for six weeks or two months from injury to see if the erstwhile complete lesion becomes a partial one. If it does not, and this must be confirmed by a careful clinical examination and electromyography, exploration should be undertaken with no further delay.

The reason for waiting up to two months in these circumstances is that sufficient time must be allowed for the scarring of the neuroma to mature. Terminal neuromata define themselves sooner, in the matter of a few weeks. If, however, the nerve has been contused over a distance, œdema takes longer to diminish and palpation as a means of distinguishing between normal and abnormal texture will not be accurate. Palpation assisted by inspection is still the best method of knowing the confines of the neuroma, that is to say of deciding how much nerve to resect to obtain healthy tissue for suture.

The nerve is exposed at the wrist by the conventional incision in vogue for displaying the carpal tunnel. Probably the nerve will be lying in scar tissue. The proximal end of the nerve is found where it lies among normal relations in the lower part of the forearm and it is traced distally until the end bulb is freed. Similarly the distal end of the nerve trunk is identified in the palm. It is traced proximally until the smaller end bulb is also freed. If spontaneous co-aptation has occurred, and the nerve is in some sort of spurious continuity, both ends of the nerve should be found in the same manner. The two approaches converge and finally the neuroma of union is fully exposed (Fig. 65). The nerve is now exposed and ready for trimming preparatory to suture (see p. 44).

The Partial Lesion. This lesion is defined as a state of imperfect conduction in which no further recovery is probable. It represents a lesion in continuity with a neuroma more or less blocking conduction. It must be recognized that surgery has nothing to offer in a partial lesion, unless the neuroma is excised and continuity restored by suture. In the median nerve at the wrist this involves transection of the nerve above and below the neuroma, sacrificing many or few normal axons according to the amount of conduction. Local excision of a lateral neuroma, though theoretically possible and beautifully illustrated in the books, is rarely worth while at this site.

The initial difficulty arises in deciding when recovery has ceased. If the area of anæsthesia is decreasing, or the quality of sensation in a given area is improving, well and good. If thenar motor power is increasing this denotes axon regeneration. The ever-present catch about the ulnar innervation of the flexor brevis pollicis must not trap the surgeon into thinking that the median nerve is recovering when it is not.

Recovery that proceeds steadily is likely to be useful recovery and conversely recovery that is slow and uncertain will probably never be of much use. In the latter instance the lesion should be explored so that it can be seen and palpated. It is in this situation that experience counts for more than muscle tests and nerve stimulation. A small lateral

neuroma partially blocking conduction has a good prognosis for resection and nerve suture. Whether this is necessary or wise depends on the type of conduction present. If adequate sensation is present with no motor power, resection of the neuroma would probably be unwise. If there is inadequate sensation or none at all, with some motor power in the thenar muscles, resection and suture would be called for.

A diffuse neuroma, whatever its texture, has a poor prognosis following resection and suture; whereas a discrete and hard neuroma is more favourable. The type of neuroma must be weighed against the present conduction in deciding whether or not to resect and suture. If there is a good deal to lose, the surgeon must be cautious; if there is nothing much to lose the patient may have much to gain if the surgeon is daring.

Neurolysis, beloved of the old masters, is rarely carried out now, largely because it seems to do no good. It was reserved for a nerve lying in a bed of scar with diffuse fibrosis and poor conduction. In conception a neurolysis is like a gambler betting each way with his last shilling. He cannot recoup his losses.

Division of the Median Nerve at its Termination

Repair of injury at the point where the nerve divides into its terminal branches is extremely difficult. The surgeon finds a stump of nerve trunk and perhaps six terminations. He is apt to feel discouraged. Usually it is impossible to obtain a good result following a division at this site. It is just worth while making an attempt to implant the digital nerves into the end bulb of the main trunk because sometimes a form of protective sensibility is restored. This may be a good deal of use in some occupations in protecting the hand from injury. There is no hope of restoring motor ability following division of the nerve at this site (Fig. 5).

Division of the Motor Branch of the Median Nerve

The motor branch of the median nerve may be divided by a penetrating wound of the palm. The disability, from the point of view of muscular function in the hand, is the same as though the median nerve had been divided at the wrist. In all instances where a puncture wound in the palm has caused complete loss of function of the thenar muscles, exploration will have to be undertaken sooner or later. Often the flexor longus pollicis tendon is damaged too. Primary treatment is confined to skin suture and restoration of movement. When this has been accomplished, this part of the palm should be exposed in the orthodox manner and the end of the median nerve trunk sought. When it is found it may be possible to make out, in the localized scar tissue, the divided motor branch passing at right angles from the main nerve into the thenar muscles. On some occasions it is possible to find both ends and to effect a suture. The prognosis is inestimable but sometimes, at any rate, some function has been restored.

Treatment of an Irreparable Median Motor Nerve Lesion

The main disability following division of the motor branch of the median nerve is that the thumb cannot be opposed. Grasping is very deficient. The flexor brevis pollicis is, however, more frequently innervated by the ulnar nerve than was realized. In a low median nerve lesion, with ulnar innervation to the flexor brevis pollicis, the disability may not be sufficiently great to merit reconstructive surgery. In such an instance the thumb does not fall back to the plane of the fingers and so remains relatively useful. The decision to remedy the irreparable lesion must depend on the disability and not on the existence of the lesion.

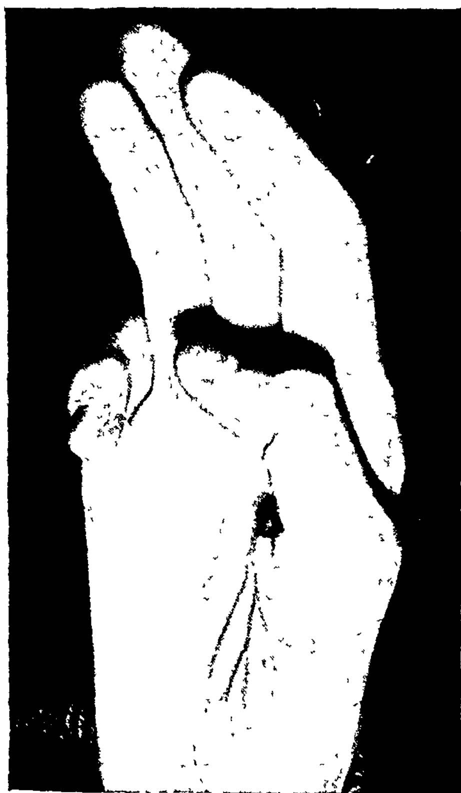


FIG. 66 (*a*). Attempted opposition of the thumb with thenar paralysis.



FIG. 66 (*b*). After transferring the sublimis of annularis to mimic thenar action a passable opposition can be obtained.

(*By courtesy of Mr. A. G. Apley*)

In the past, several methods have been advocated with the idea of maintaining the thumb in the opposed position. They consisted, usually, of arthrodesis, in one form or another, of the first metacarpo-carpal joint in the position of function. More recently Bunnell has described a method of tendon transfer whereby controlled opposition of the thumb is restored.

This method makes use of the sublimis tendon of the ring finger of the same side which is re-routed so that it mimics the effect of the opponens pollicis. The tendon is approached by a lateral incision over the middle phalanx. It is divided at its insertion into the bone and the

the original wound is healed, in which case, if the ulnar nerve was damaged, the lesion will be established. Without information concerning the findings at primary surgery, the surgeon will have to determine by clinical examination the condition of the nerve. If it is not conducting, an exploration may be necessary.

The Complete Lesion. It will be remembered that the injury which divides the ulnar nerve is very likely to damage the long tendons of the fingers and the flexor carpi ulnaris. This should be borne in mind when testing function of the fingers as a method of evaluation of conduction. The recognition of the signs of a complete ulnar nerve lesion on the sensory side is straightforward. There is total loss of cutaneous sensibility to cotton-wool and to pin-prick over the area of anatomical distribution of the nerve. In all probability the back of the minimus

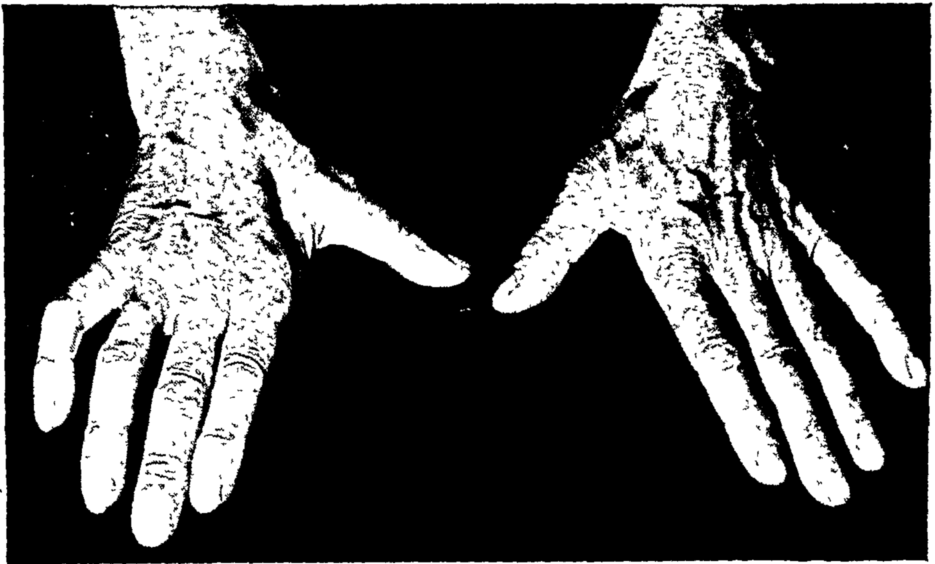


FIG. 67 The wasting in the first interosseus space denotes an ulnar nerve palsy. The claw hand deformity is also present.

and ulnar border of the hand will be spared, as the dorsal branch of the ulnar nerve leaves the main trunk two fingers' breadth above the ulnar styloid. In addition the skin will feel dry and thin and will have lost its 'tackiness.'

The motor aspect of the nerve is affected in an obvious way. The palm is narrowed by loss of substance of the hypothenar eminence. The ulnar border of the fifth metacarpal is unusually prominent because the hypothenar eminence is thin and excavated. Moreover, wasting of the thenar adductor muscles gives the first interosseous space a quite characteristic appearance. Normally a good deal of muscle is palpable between the palmar and the dorsal surfaces of the space. With an established ulnar nerve lesion the examiner can feel that the radial margin of the second metacarpal is very prominent, because of wasting of the first dorsal interosseous muscle, and there is little tissue between the two

layers of opposing skin. In a lesion which has been present for some time the dorsal tendons and metacarpals are more prominent than usual because of wasting of the intervening interosseous muscles (Fig. 67). The volar surface of the palm has a curious, simian appearance, as though there is loss of substance within the palm. This accentuates the prominence of the metacarpal heads. This hand cannot hold water.

Probably the best test of muscle action consists in asking the patient to separate the fingers when they are fully extended. The absence of any contraction of the hypothenar group is instantly detected. An ulnar claw hand deformity is usually present but this is a capricious sign of an ulnar nerve lesion because occasionally the deformity is absent. Fixed deviation of the little finger on extension of the fingers is a more constant sign.

The Partial Lesion. The condition found on examination when the lesion is partial is, of course, extremely variable. A partial lesion denotes a nerve trunk injured in continuity. Sometimes the lesion of the nerve is dominantly on the sensory and sometimes on the motor side, but more often it represents a damage of both motor and sensory fibres. The diagnosis of a partial nerve lesion is extremely easy. There may be some conduction of sensation still present. Appreciation to cotton-wool may be absent and the acuteness of sensation to the pin-prick may be dimmed. In making this test the surgeon must be careful that the pin is sharp, otherwise deep sensibility conveyed by tendons may be accepted as imperfect skin sensibility. In a partial nerve lesion it is probable that the skin will be moist; at least not so dry as it is in a complete nerve lesion. From the aspect of motor ability, a partial nerve lesion is extremely variable, but it will be found on examination that the wasting of the groups of muscles supplied by the ulnar nerve is neither complete nor uniform and, further, it may be possible to demonstrate that there is some voluntary activity in one or more groups of muscles supplied by the motor branch. Having established that the ulnar nerve lesion is partial, the surgeon will wish to know whether there are signs of continuous improvement. If repeated examinations show that there is improving conduction, both on the motor and on the sensory sides, surgery is not to be contemplated until or unless improvement stops short of a reasonable function.

The Irritative Lesion. From time to time an irritative lesion of the ulnar nerve will be met with. Clinically there may be spontaneous pain in the region supplied by the ulnar nerve, emphasized probably on movement of the wrist, together with hyperidrosis and an unpleasant sensation of a spreading nature experienced as a result of painful stimulus such as sharp pressure or a pin-prick. There is weakness and wasting of the ulnar intrinsics and on occasion fibrillary twitchings of the hypothenar eminence may be observed. An irritative lesion of the ulnar nerve, as of other nerves, always denotes that the nerve is in continuity. It may occur when the lesion has always been incomplete, or it may represent a transitory stage of nerve recovery following suture.

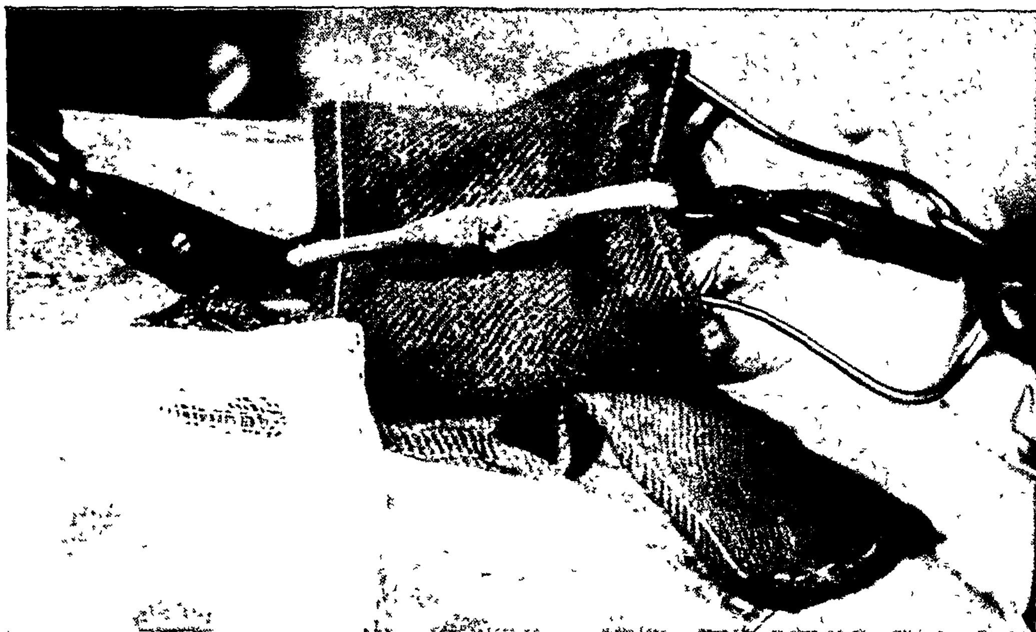


FIG. 68. A complete ulnar nerve lesion in continuity requiring resection and suture after transposition.



FIG 69. This ulnar nerve was exposed during a tendon repair Clinically a partial lesion was present It was considered wise to accept the known conduction. Exploration was not helpful in arriving at the decision.

Treatment of the Established Ulnar Nerve Lesion

The Complete Lesion. The policy and method of treatment of the complete ulnar nerve lesion is similar to that of the median nerve. Repetition is unnecessary. The approach to the nerve must be adequate. A free incision along the ulnar aspect of the lower forearm and hypothenar eminence will define a flap, sufficiently broad based, to be retracted radially, allowing exposure of the nerve (Fig. 68). The surgeon should always be ready to transpose the nerve at the elbow at the time of suture at the wrist, if the increased tension requires it.

The Partial Lesion. Surgery is not contemplated for the partial lesion until spontaneous improvement has ceased. Surgery of the partial lesion is a gamble. The present known conduction is bet against enhanced future function (Fig. 69). If conduction is already fair, the patient has little to gain; if it is poor, he may win a lot on an outside chance. In the case of the ulnar nerve, motor conduction is the criterion on which function is judged. The surgeon must assess the usefulness of the functioning ulnar intrinsics. On this he will base his decision to operate.

Exploration, implying a fact-finding operation, has little to offer in nerve surgery. No new information is available merely because the nerve can be seen. Direct electrical stimulation reveals nothing new in the case of a partial lesion in which recovery has ceased. Therefore, all available information should be at hand before surgery, and here electromyography comes into its own. By this method of investigation it can be found out exactly which muscles are working and to what extent. Sometimes, as a result of electromyography, the surgeon may decide that physiotherapy, designed to train specific muscles, will stand a better chance of improving function than resection and suture. Electromyography may reveal a more accurate picture of the true state of affairs than clinical examination garnished with wishful thinking. The surgeon has to decide whether to operate or not. If he operates it will be to resect a neuroma and to suture; not merely to explore.

The Irritative Lesion. If the irritative lesion is, in fact, over-reaction of nerve recovery, no specific treatment is called for. On the other hand if the irritative lesion is noticed soon after the injury and the amount of conduction of the nerve does not alter, the lesion is intrinsically irritative. In some instances the patient has more disability than he would have with a complete lesion. If the irritative phenomena are exaggerated, in spite of reasonable conductivity of the nerve, it is wise to resect the affected part of the nerve following this by end-to-end suture. As functional recovery following suture cannot be guaranteed, such treatment is reserved for those instances of irritability when conduction is poor and spontaneous pain aggressive.

Division of the Deep Branch of the Ulnar Nerve

Division of the motor branch of the nerve may be caused by a pene-

trating injury at the level of the pisiform bone. It is an uncommon injury by itself. It may complicate division of the flexor tendons to the ring and little fingers and in such instances is liable to be associated with division of the sensory terminal branch of the ulnar nerve as well. The symptoms and signs are well known. Occasionally branches to individual muscles may be divided, leaving others intact, but then the lesion is of academic interest only. A complete motor lesion is the rule.

The treatment of a complete division of the motor branch of the ulnar nerve is a matter of surgical approach. After a tourniquet has been applied, a longitudinal incision is made along the lower third of the ulnar aspect of the forearm, continuing into the palm to the medial side of the pisiform bone. With reflection of the skin flap in the radial direction, sufficient access can be obtained.

The ulnar nerve is found where it lies in normal surroundings in the lower part of the arm, and traced distally until the site of damage is reached. Just distal to the pisiform bone the ulnar nerve divides into its terminal branches. The motor element plunges deeply between the two heads of the opponens minimi digiti (Fig. 6). The names of the muscles of the hypothenar eminence are of no importance to the surgeon who is following the deep branch of the ulnar nerve into the palm. The hypothenar muscles on the radial side of the motor branch may be detached from the pisiform and hook of the unciform and this gives sufficient view of the nerve before it crosses the floor of the palm. If the nerve has been damaged at this site, and the scarring is not too extensive, suture may be possible although difficult. Three or four stainless steel wire sutures are used to secure apposition of the nerve ends. Usually the conditions are disappointing, in which case the prognosis is poor.

Henry has devised another approach to the motor branch of the ulnar nerve, in which the pisiform bone is lifted from its moorings and the flexor brevis minimi digiti is separated from the volar surface of the fifth metacarpal shaft. The skin incision is similar to that used for the approach previously mentioned. The flexor carpi ulnaris, together with the pisiform bone and the flexor brevis minimi digiti are retracted forward and the ulnar nerve can be traced as it decends from the forearm into the basal layer of the palm. In certain instances of scarring, following injury, this is an easier approach through which to obtain a suture.

The occasions when this performance may be necessary are few and far between but it is possible to approach the nerve by these means and the result obtained will depend on the technical quality of the suture obtained. Caution must be exercised before deciding that attempted suture is a wise procedure.

The Closed Lesion of the Deep Branch. Sometimes a lesion of the deep branch of the ulnar nerve occurs without injury. It is seen in patients who have recently taken to elbow crutches or sometimes in terrazzo workers who kneel leaning forwards taking weight on the outstretched hand.

The lesion is originally of the neurapraxia type and recovers soon

after the habit of pressure is changed. If of longer duration recovery may not be complete after relief of occupational pressure. Probably in such an instance an intra-neural fibrosis has occurred similar in type to that which happens at the elbow region.

The diagnosis is obvious because sensory conduction is not affected. Treatment consists in relief of the nerve from pressure at the level of the pisiform bone, that is to say altering habits or occupation.

The Irreparable Lesion of the Ulnar Nerve

Disability due to loss of action of the intrinsic muscles of the hand is not trivial and may be of great significance in some occupations. It is true that there may be no impairment of use for such actions as grasping a hammer or playing golf because the power of the hand is quite good. Intrinsic loss is felt more particularly in attempting finer movements of the hand. The patient complains of a sense of clumsiness and delicate use of the hand is totally debarred. On attempting to flex the fingers it will be seen that the terminal joints begin the movement, followed by the proximal interphalangeal and finally the metacarpo-phalangeal joints. It seems as though the fingers are wrapping themselves up. Normally, on attempting to grip an object, all the joints begin to bend synchronously.

After some brilliant reasoning, a method was devised whereby the two terminal slips of the sublimis tendon were detached from the middle phalanx and moved dorsally a few millimetres and inserted into the two lateral slips of the finger extensor tendon. The resultant movement from sublimis action would closely mimic interosseous function. The clever conception of Makins, elaborated by Bunnell, does not always work out so well in practice but it is the only method whereby surgery, by tendon transfer, can materially neutralize intrinsic loss to a patient who needs fine, controlled hand movement. Being essentially reconstructive in nature, the method is not described here.

THE DIGITAL NERVES

In the Palm

The digital nerves as they cross the palm, whether of median or ulnar derivation, are vulnerable to injury. In instances of injury there will usually be associated damage to neighbouring tendons. The loss of conduction of the nerves should be recognized at superficial clinical examination before primary surgery. According to the areas of sensory loss, the number of divided digital nerves can be known exactly.

When the wound is investigated and the tendon damage is assessed, the divisions of the digital nerves will also be seen (Fig. 70). The aim is to suture, if possible, the nerves at the time of primary surgery. If there has been loss of nerve substance, or if the nerve is badly contused and liable to fibrosis, suture may be impossible or of no avail. Successful suture will not be possible unless the necessary skill and instruments are

to hand. Cleanly divided nerves should be sutured as accurately as their size permits with fine stainless steel sutures. If there is contusion or

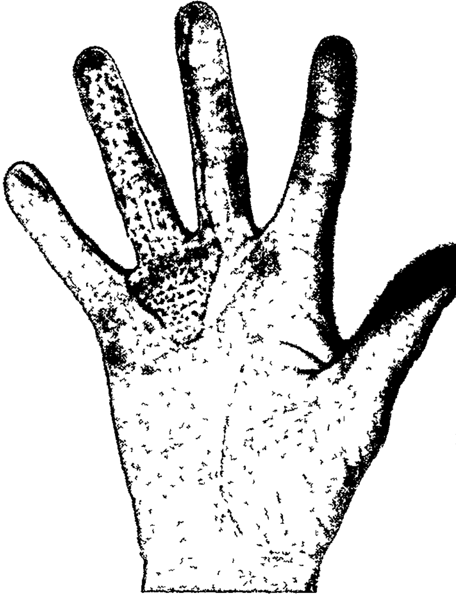


FIG. 70 (*a*) A chisel was run into the palm at the level of the transverse palmar crease proximal to the annularis dividing both tendons, the digital nerve to the third cleft, and damaging the nerve to the fourth cleft.



FIG 70 (*b*) At delayed primary suture the proximal tendon ends are retracted. The divided nerve is held in artery forceps.



FIG 70 (*c*) The nerve has been sutured The sublimis has been sacrificed and the profundus has been sutured by the withdrawable suture technique.

damage to the nerve, co-aptation with a coarse suture material may be all that is possible. Abundant scar tissue is apt to form in the palm and unless the nerves are sutured, or at least brought together at primary

surgery, they will be found at a later date, to be retracted, adherent and fibrotic and almost impossible to suture.

The argument set out on p. 44, advocating deliberate secondary nerve suture, is still maintained in general. In the case of digital nerves, however, this is better waived because of the difficulties of secondary suture, especially in the digits. After conservative excision of the end bulbs, the tension is usually too great and the chances of mobilization too slight to permit of a good suture. Often a secondary nerve suture has to be carried out because no earlier opportunity presents itself. At this time the nerves are approached through a planned incision in the palm. They are easily identified by their colour and constant position. The proximal end bulb will be large; the distal will be smaller. After end bulb excision there may be a wider gap than is desirable and so there is apt to be unpleasant tension at the junction. Inevitably the suture line will be below standard. Some relief of tension is obtained by flexing the fingers but this position makes surgery more difficult and hæmatoma formation more likely.

The surgeon may have an opportunity of demonstrating his skill by performing a nerve graft as a *tour de force*. There is no doubt that a nerve graft can be successful. Equally, nerve to be grafted is available from a subcutaneous sensory nerve of the forearm. If after excision of the neuromata there is a gap of an inch or more, the only way to close it is by a nerve graft. No nerve advancement is possible. The median cutaneous nerve of the forearm is sought and the appropriate length removed. It is placed in the gap and sutured at each end. The subsequent surgical management is obvious. The occasions justifying a nerve graft in the palm are rare. Each nerve innervates a cleft and so two adjacent nerves must be divided to denervate a finger. It is probable that the digital arteries and tendons will also be damaged, leaving a stiff and perished finger. If the finger is mobile, a double nerve graft could be considered. A nerve graft for damage to a single digital nerve is never called for.

If by chance one or more of the digital nerves are divided exactly at the point where they emerge from the median enlargement, suture is extremely difficult and the chances of success are slight. A successful secondary suture at this site is almost impossible, so that primary suture should be undertaken if possible as the results, though capricious, are likely to be better. If the two sensory terminal branches of the ulnar nerve are divided in similar circumstances at the point of division from the deep branch, the difficulties of suture are similar to those for the median nerve and the results are equally poor.

It is always worth while attempting to suture a digital nerve in the palm. Sometimes the result is poor but frequently, in spite of unfavourable circumstances, the patient will achieve an enhanced amount of sensation in the finger. Digital nerve suture in the palm is considered by many surgeons to be an essential prerequisite of reparative tendon surgery.

In the Fingers and Thumb

Division of digital nerves in the fingers may only be of small significance. Joint position sense is not lost if the tendons are intact and functioning. It is rare for both digital nerves to be divided at one injury. Single digital nerve divisions in the fingers are apt to be overlooked, or at least neglected in the early stages. The wound in the finger may be relatively trivial and will be nearly always transverse. The accompanying tendon damage is often deliberately left alone for a time and so the digital nerve is likely to receive similar treatment.

Immediate digital nerve suture is more rewarding than secondary suture, and so as a counsel of perfection, it is often advised that divided digital nerves should be sutured at primary skin repair. This is impracticable in the out-patient theatre under local anæsthesia. If the wound is trivial the patient may not seek advice immediately, or if he does, the nerve damage may not be suspected. The nerve is more likely to be sutured in extensive lacerations when it is exposed and suture is easy. The next best thing, a delayed primary suture at the time of tendon repair is probably the best that can be hoped for.

If the injury is sufficiently extensive to damage both digital nerves, the flexor tendons will surely be divided and there is more than a possibility that the patient would be better with the finger amputated. Associated damage to the digital arteries causes the pulp of the finger to be meagre and blue. If an attempt is planned to restore tendon function by suture or grafting it is necessary, successfully, to suture one digital nerve as a preliminary.

It is not easy, and hardly practical, to approach both digital nerves at the same operation. The surgeon will be wise to attempt to suture the digital nerve on the least injured side of the finger. The nerve is approached through a longitudinal lateral incision, centred on the site of injury. The incision will probably extend throughout the length of the finger. The palmar flap is retracted and the normal proximal part of the nerve is identified and traced towards the site of injury. Similarly the distal end of the nerve is found at a distance from the site of injury and traced backwards towards the proximal end. The neurofibromata and scarring are excised. A formal suture is carried out by means of the finest stainless steel wire stitches. If the surgeon is serious in his intentions to restore function in the future he may take the opportunity of removing the remains of the condemned tendons at the time of nerve suture. A second incision into the finger may thereby be avoided. When the suture is complete, the skin is closed and a pressure dressing is applied. At the end of three weeks the dressing is removed and efforts are made to restore passive movements of the finger. As soon as recovery in the nerve is recognized, and this may not be for two months or so, reparative tendon surgery may be planned and carried out.

Unless a single digital nerve division is sutured at the time of primary surgery it is not repaired as a separate set-piece. At the completion of a

tendon repair a single digital nerve may be sutured if opportunity serves. As time passes the area of skin insensibility due to a divided digital nerve is reduced to a tiny patch on the side of the distal interphalangeal joint. The encroachment of sensation from the opposite side of the finger is a fact of life that deceives enthusiastic surgeons into a belief in recovery after digital nerve suture. Frequently the surgeon steals the credit from nature. The inference in the case of division of both digital nerves in one finger is obvious: amputation (see p. 62).

CHAPTER 8

INJURIES OF THE BONE

FRACTURES

Fractured Scaphoid

This fracture has been recognized and treated for half a century but the bone has not yet yielded up all its secrets. The scaphoid, like the neck of the femur, has a sinister reputation. Actually there is little difficulty

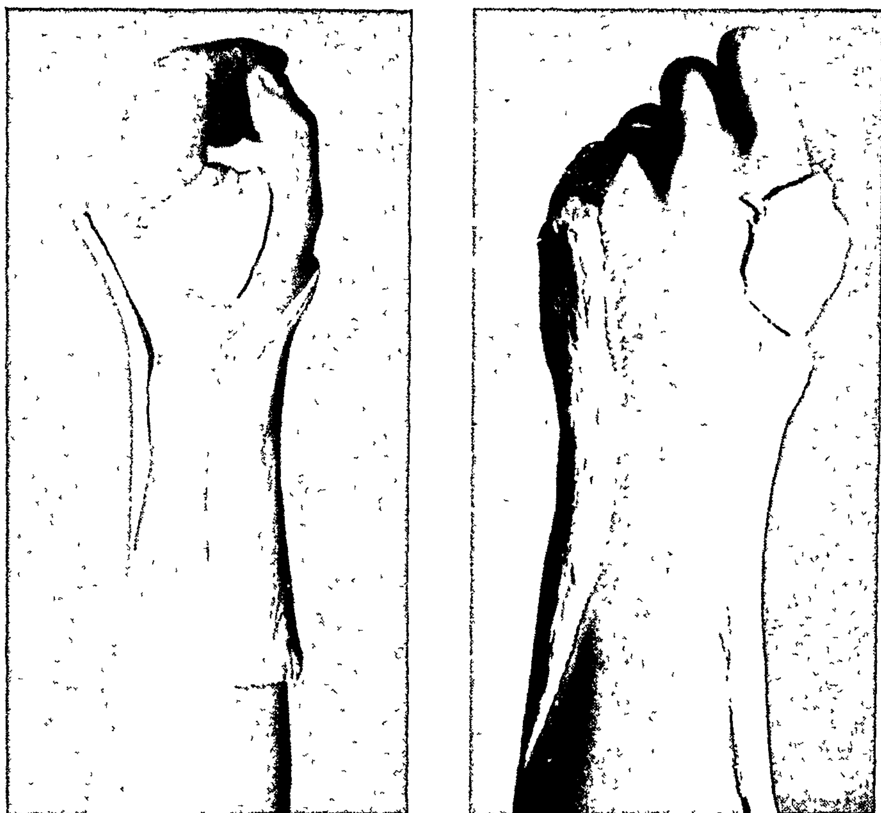


FIG. 71 The purpose of the splint for the fractured scaphoid is to control hinge movement and axial deviation Naturally the plaster will be held by a bandage

of securing union in a fresh, uncomplicated fracture if it is immobilized long enough and efficiently. Unfortunately fractures of the scaphoid occur in healthy young males and splintage for three months is a grave disability. Circumstances encourage the surgeon to reduce the time of fixation beyond the minimum to secure union.

The diagnosis may be overlooked in the first instance. A negative X-ray supports the impression that the wrist is merely sprained. When the symptoms persist and the fracture is revealed by a later X-ray, a

golden opportunity for early fixation is lost and a modified result is to be expected.

Ætiology. A fall on the outstretched hand, or similar force, is necessary. Pure dorsiflexion is not enough. The force must also cause radial deviation. This combination shears the scaphoid across the waist, because the one part of the bone is held immobile with the proximal row of carpal bones and the distal part moves radially with the distal row.

Diagnosis. In an early instance a history of injury is available, though the local signs may not be very gross. There is limitation of wrist movement of variable degree and local tenderness over the scaphoid itself. The diagnosis, though suspected clinically, is made by the X-ray. A fracture line is seen to extend across the waist of the bone.

On some occasions, in spite of a convincing history and signs, X-ray reveals no fracture. All such instances should be observed and X-rayed again in three weeks if symptoms and tenderness persist. Often a suspected but unproven fracture is revealed by the subsequent picture.

Treatment. The aim of treatment is to secure union and this is achieved by external fixation with plaster of Paris. Traditionally the wrist is held dorsiflexed and the thumb is immobilized to include the proximal phalanx in the position of function. Fixation is for twelve weeks, when union of the fresh and uncomplicated fracture is usually complete. Attempts to reduce the time of splintage have been made in the past and usually they fail to secure union.

The traditional splint is formidable and cumbersome. The external splint can, however, be reduced in size and weight. A plaster splint to maintain moderate dorsiflexion and prevent axial deviation of the carpus is all that is required. Neither the thumb nor the fingers need be involved in the splint (Fig. 71). The essence of treatment is to prevent deviation of the hand, which produces a shearing force at the fracture line. The splint must, however, be worn for twelve weeks. Attempts at internal fixation of the fracture have been and are being made. The prospect is attractive. A small operation to secure reduction and maintain position almost carries with it a guarantee of union and the cumbersome splint is dispensed with. The search is on, but a reliable technique has yet to be found.

The Fracture Recognized Late. For many reasons, avoidable or unavoidable, some fractures of the scaphoid are not discovered for several weeks after their occurrence (Fig. 72). At that stage it is not easy to decide whether to aim at union of the fracture or to be content with non-union. The unfortunate truth is that if an attempt to secure union by prolonged immobilization should fail, the patient is worse off than if no attempt to secure repair had been made. If the fracture is discovered within two or three weeks of its occurrence, the probability of union is very good if splintage is adequate both as regards extent and duration. Beyond that time, and especially if the X-ray shows some absorption at the fracture line, splintage is unlikely to lead to union and treatment by

immobilization may not be worth while. The decision has to be made individually and if it is thought that the chances of union are slight no splint should be applied. Active use, normal and specialized, will soon restore a full range of motion. Many patients with fractured scaphoids are able to do hard and prolonged work and it is only a proportion of these who ever seek advice of a surgeon at a later time because they have sprained their non-union.

The Treatment of Non-Union. Non-union is a controversial subject. Activists go to great pains to secure union by surgery or by prolonged



FIG. 72 This scaphoid will never unite by prolonged fixation. It should not be splinted Late mechanical arthritis is more likely when fixation has been tried and failed than when it has not been tried at all.

fixation. Their opponents claim that non-union need not inevitably be a disabling condition and prefer to accept it. The aphorism attributed to the late Professor MacMurray should be borne in mind by the surgeon as he evaluates the necessity and chances of securing union by surgery. The aphorism is roughly as follows: a scaphoid of the correct size and correct shape, united or ununited, is a good scaphoid: a scaphoid of incorrect size and incorrect shape, united or ununited, is a bad scaphoid. This may only partially be true but its import is that grafting of the scaphoid is not justified. The surgeon may sometimes be faced with an occasion when he believes it necessary to secure union and that grafting

is the only means available. The operation is technically tricky and specialized works on technique should be consulted. It is, however, quite possible in a high proportion of instances, to unite by grafting a scaphoid that has been ununited for many months. Bony union will be complete at the end of six or nine months and the scaphoid will be restored to its pristine rigidity. Whether this, in fact, will assist the function of the wrist is doubtful.

If the major disability of non-union is pain on forced or full radial



FIG 73 The tip of the radial styloid has been stepped down and removed from the vicinity of the pseudarthrosis.

deviation, this symptom can be neutralized by stepping down the tip of the radial styloid in the manner shown in Fig. 73. The operation is easy, and reliable if the indicative symptom is present.

From time to time it will be obvious that the essential cause of non-union of the scaphoid is death of the proximal fragment. If, after some months, the proximal fragment of the bone shows increase of density by X-ray compared with the other carpal bones, it can be assumed that it is in the state of aseptic necrosis. This condition is reversible and it is possible by grafting to revive the dead fragment. This does not mean that the function of the wrist will be much good. In spite of technical success

a painful arthritis is bound to follow the prolonged immobilization which is necessary.

Excision of the dead proximal portion of the scaphoid has been advocated as a means of alleviating the disability. This operation by itself is unsatisfactory and does not produce the looked-for relief. Marsden advocates removal of the whole of the scaphoid (Fig. 74). The bone is approached from the radial aspect, the tip of the styloid process being removed to obtain access. The approach itself is innocuous. Although the tip of the styloid process is sacrificed, the wrist soon becomes stable. The results are impressive and often permit the patient to ' soldier

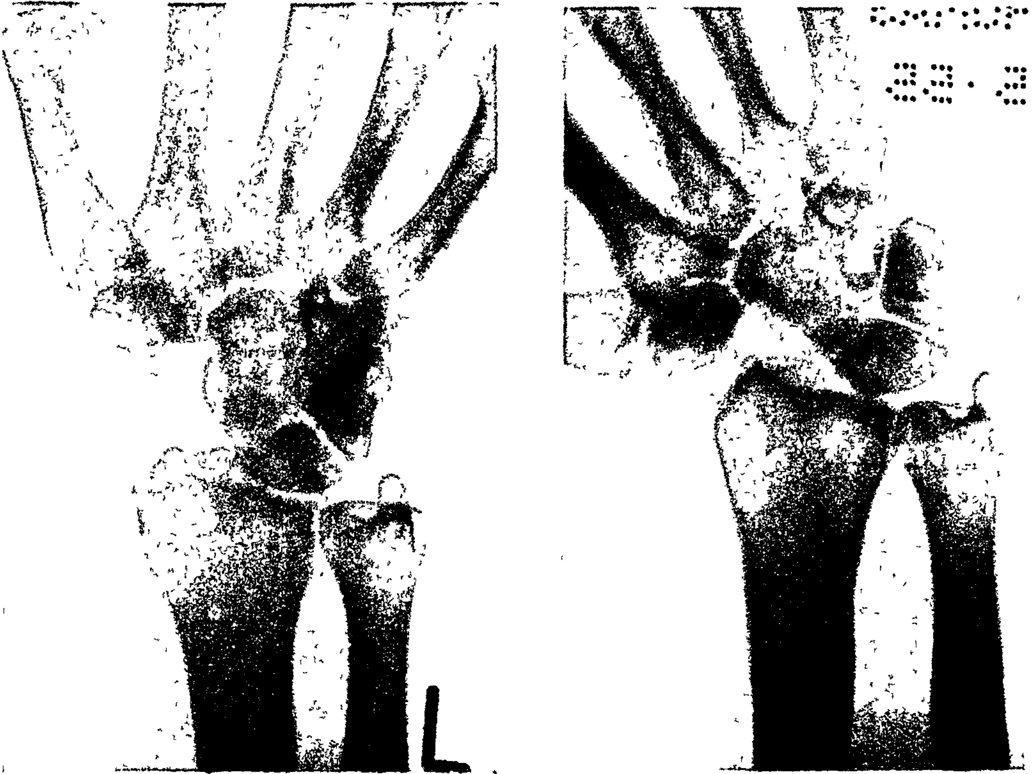


FIG 74. After removal of the whole of the scaphoid much movement is possible. There is also adequate stability.

on ' in a high category. Excision of the whole of the proximal row of the carpal bones has its advocates. A relatively unstable but mobile wrist is obtained and in all but heavy manual workers this pseudarthrosis proves serviceable and useful for many years.

The Treatment of Mechanical Arthritis. Arthrodesis of the wrist has had a vogue as a means of alleviating the arthritic disability which occurs late in the history of a fractured scaphoid which has had a checkered career. This operation has a good reputation. The disability of a fixed wrist is not great and the results are less capricious and more useful for a manual worker than those obtained by excision of the carpal bones. Arthrodesis of the wrist for mechanical arthritis following non-union

of the fractured scaphoid is in the repertoire of all orthopædic surgeons. The technique is not easy. Failure may follow; but if the operation is skilfully performed, and especially if a bone graft is used to bridge the gap between the lower end of the radius and the third metacarpal, it is likely that sound consolidation will follow. If the arthrodesis is made with the wrist fairly well dorsiflexed, and without radial deviation, the hand will be almost as useful as it was before the accident causing the fracture.

Bennett's Fracture

A Bennett's fracture is a fracture-dislocation at the base of the thumb. The proximal part of the metacarpal is fractured obliquely and a small fragment of the bone remains in correct relationship with the trapezium. The main fragment of the metacarpal is displaced radially and proximally. The force which causes this fracture is a longitudinal one, combined with abduction of the thumb.

Diagnosis. The history of injury, together with inability to use the thumb, and pain on attempting to do so, with swelling at the base of the thumb, are almost diagnostic. Careful examination will detect that the thumb is short. The bony displacement is often impalpable as it is hidden in the swelling. There is local tenderness over the carpo-metacarpal joint. The X-ray is confirmatory and characteristic and differentiates the fracture from a pure dislocation.

Treatment. According to tradition it is correct to treat a recent fracture by reduction, which is maintained by splintage until stability is assured. Stiffness, which develops during fixation, is accepted and got rid of by physiotherapy. Often, however, the reduction is imperfect. It therefore seems a waste of time to treat patients in this manner, if at the end of the period of splintage reduction is found to be partial. The fracture might as well remain unreduced completely. The principle of treatment is not at fault but the method of its application is inadequate. Long axis traction on the thumb, applied by strapping is useless and that by skeletal wires or pulp traction is barbarous. Pressure at the base of the metacarpal, to be effective, is liable to cause skin necrosis.

For these reasons opinion has changed and some surgeons feel it better to make no attempt to reduce the fracture. The patient is treated by early active and passive motion in order to restore movement to the damaged joint. Painless movement can easily be restored in a few weeks. Abduction of the thumb is limited for a good deal longer, sometimes several months, but ultimately full strength and motion are restored. A thumb treated on these lines is more than likely to become normal in function, though remaining abnormal in appearance.

Such a cosmetic result would not be acceptable to those, such as a manicurist, whose appearance depends on the hand. Activist surgeons, who are unable to leave the displacement unreduced, have no alternative but to reduce the fracture under vision, followed by internal fixation. Successful closed reduction of a fracture is hazardous. If reduction is

necessary, the surgeon must throw off the fetters of the past and operate.

A tourniquet is used and the surgical approach is simple and attractive. A curved, flap-raising incision readily displays the fracture and confirms the accuracy of the reduction. Short lengths of Kirschner wire are inserted through the main or distal fragment, holding it to the carpus. The wires enter the carpus in different directions, irrespective of anatomy, and the fixation is firm. They are cut off to leave a $\frac{1}{4}$ inch protruding through the skin. The wound is sutured and crepe bandage compression

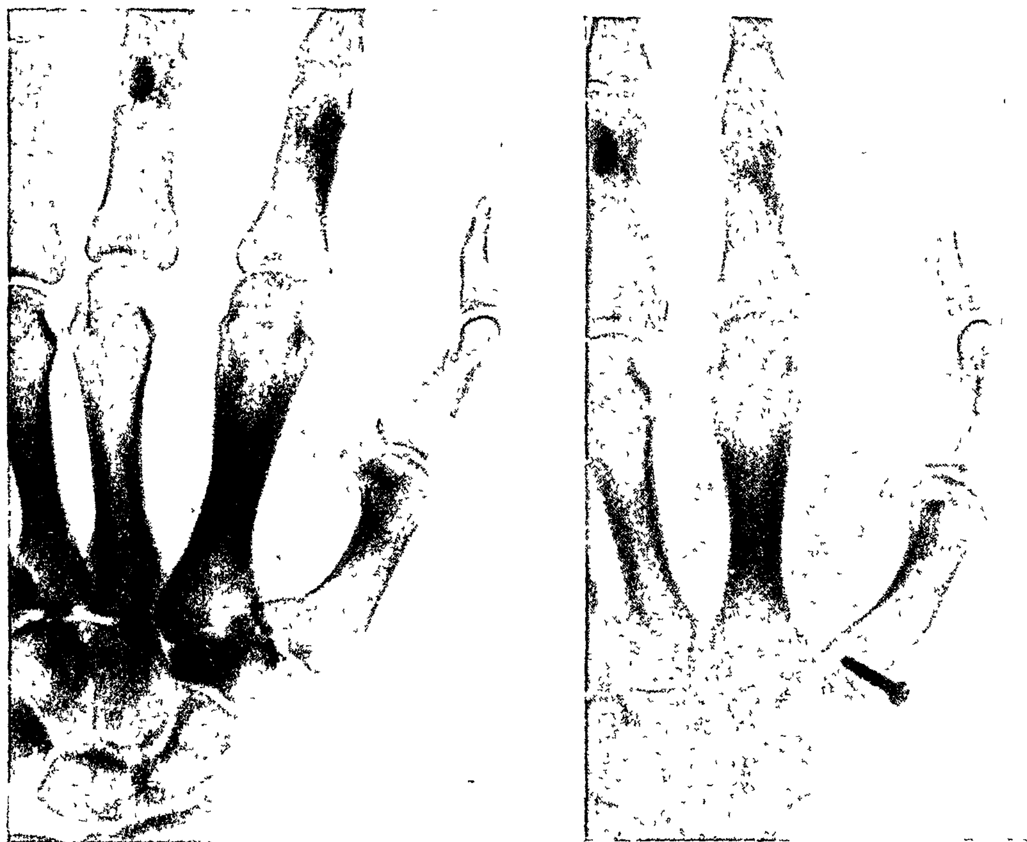


FIG 75 The separated fragment of the Bennett's fracture is effectively stabilized by a screw (*By courtesy of Mr. Pickering Pick.*)

is applied to control swelling. In three weeks the wires are removed but crepe bandage pressure is maintained for another week.

The reduction can often be held by a small screw passing transversely across the base of the metacarpal into the fragment (Fig. 75). If this can be done a brilliant result is obtained in a few days, following the removal of the post-operative crepe bandage compression.

These methods of treatment, though a little more elaborate, are ideal: they give the best appearance and the problem is mastered. They are unnecessarily elaborate for a labourer or a dirt track rider who can be given a serviceable result in a shorter time if the displacement is allowed to persist. They are more in keeping with modern thought than the archaic

method of attempting reduction by means of pulp traction and a ramshackle plaster splint.

Fractured First Metacarpal at its Base

This fracture may be caused by direct injury or in a similar way to the foregoing fracture. In this instance the fracture line is transverse across the base of the first metacarpal (Fig. 76). Clinically the condition is so similar in appearance to a Bennett's fracture that a differential

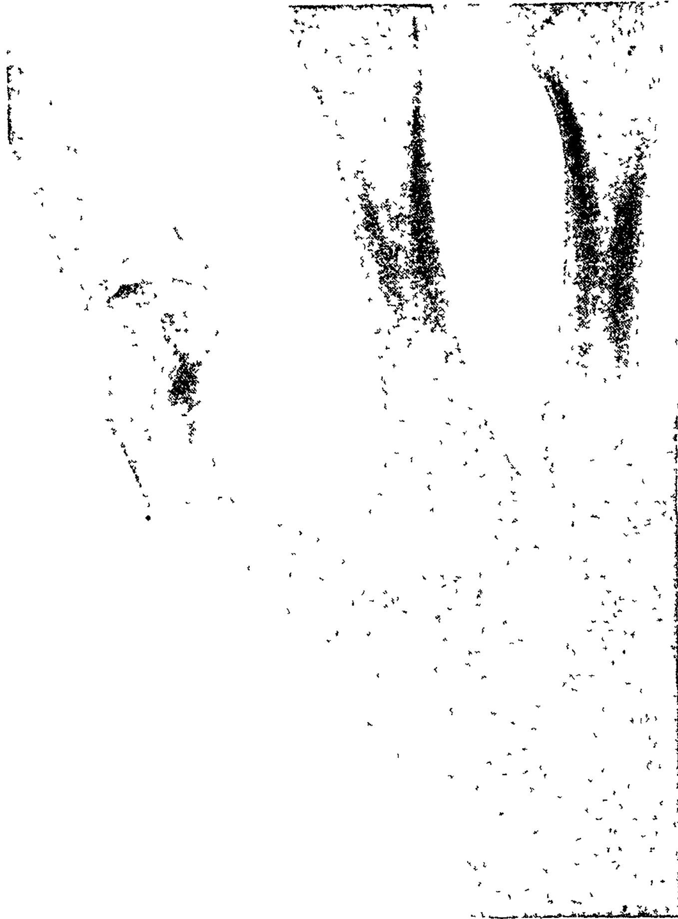


FIG. 76. This injury may be indistinguishable clinically from a Bennett's fracture.

diagnosis is not possible without X-ray whereby the difference will immediately be revealed.

Treatment. Manipulative reduction should be attempted and if stability can be obtained the thumb should be immobilized in a crepe bandage. The bandage compresses the hæmatoma and stabilizes the fracture. If, however, it is impossible to hitch the fragments, the best method of maintaining the reduction is by transfixion with a Kirschner wire after open reduction. This passes through the first metacarpal, anchoring it to the base of the second in a similar way to the method used for Bennett's fracture. At the end of two or three weeks the wire is

removed and the crepe bandage is retained for a further week. The patient is then enjoined to use the thumb as far as possible. Soon full function will return. No special reconditioning or treatment is necessary

Oblique Fractures of other Metacarpal Shafts

These injuries may result from any local, indirect violence. An amateur pugilist punching a wall in error for an antagonist's maxilla is a typical example.

Diagnosis. The skin over the knuckles may be damaged or bruised but the major pain is complained of along the course of one of the inner four



FIG. 77. This type of fracture is accompanied by a good deal of soft part swelling The X-ray is of academic interest only.

metacarpals. The patient will know which metacarpal has been fractured, but palpation except in the first few minutes after injury, is of little help because of swelling. It may be noted that the knuckle of the corresponding digit has receded somewhat. Occasionally the finger is short. The diagnosis is confirmed by X-ray and the amount of displacement is assessed (Fig. 77).

Treatment. Union is invariable. It is clinically complete in three or four weeks. Mal-union has to be prevented. Angulation is not a problem because the fracture is oblique. Shortening is slight and of no account. It is necessary, however, to prevent a rotational or tortional mal-union. This deformity, in its early stages, can easily pass unnoticed and it is not usually brought to attention until finger movement is restored. Then it is

found that on flexion the fractured finger comes into an abnormal relation with its fellow and an irritating disability is produced.

The simplest method of treating an oblique fracture of the inner four metacarpals is to fix the finger to one of its neighbours by means of a garter of elastic (Fig. 86). Flexion of the normal finger will induce movement into the injured finger and rotational deformity will be prevented. No other kind of splint is necessary and it will be evident to the patient at the end of perhaps two weeks that further restraint by means of the garter is no longer necessary. It will be abandoned.



FIG. 78 Transverse fractures of metacarpals, since they are the result of direct violence, are often compound, or at least accompanied by a contusion.

Transverse Fractures of Metacarpals

These fractures are caused by direct violence and frequently are compound and may be an incidental feature in an extensively damaged hand. They occur in industry or on the highway. The back of the hand is hit by some object breaking the skin, dividing tendons and fracturing metacarpals. Cricketers experience the fracture as a closed injury when batting without gloves on a bumpy pitch. Except in instances of considerable violence, displacement is not great so that the diagnosis is often overlooked (Fig. 78).

Diagnosis. Before swelling has obscured local contour, the diagnosis is made on account of local tenderness over a metacarpal bone, together

with some deformity. An X-ray is often the only means of making the diagnosis at all.

Treatment. In a closed injury, with only slight displacement, the treatment is the same as for the oblique fracture. A garter of $\frac{1}{2}$-inch elastic is made to hold two adjacent fingers together. Movement induced into the injured finger by means of the normal one will maintain range and control and automatically prevent rotatory mal-union. Union will be complete in a month or so and the patient will be aware when the elastic garter is no longer of any use.

When one or more metacarpals are fractured, sometimes with loss of substance, in the base of an extensive dorsal wound, treatment of the bone is of secondary importance compared with that of obtaining skin cover (Fig. 18). The cumbersome banjo splint, employing barbarous or useless traction, happily is less popular than it was. It was used as a means of controlling fractures of phalanges or metacarpals whilst leaving the skin available for inspection or treatment. Different methods are in use to-day.

If the wound can be sutured, or if cover is obtained by immediate skin grafting, the metacarpal fractures are only treated if it is considered that transfixation by Kirschner wires is appropriate. External splintage by traction or plaster of Paris is rarely used if there is a wound. If it is possible that the Kirschner wires will spread contamination, they should not be used. Movement is restored as far as possible and the fractures or mal-union are dealt with at a later time when skin healing is complete.

Fractures of Metacarpal Necks

A fracture of the metacarpal neck is nearly always caused by indirect violence on the clenched fist. The fifth finger is most frequently hurt (Fig. 79a). There is almost always angulation, convex backwards. Sometimes these injuries pass as a sprain but often it is obvious to the patient that a bone has been fractured and he seeks advice soon after the occurrence.

Diagnosis. On clinical examination it will be noted that the dorsum of the hand is swollen, particularly in the region of the neck of the metacarpal. The metacarpal head can be palpated pushing its way into the palm. On the dorsum there is a prominence at the end of the metacarpal shaft, at the site of angulation. Movement of the finger, and even of the metacarpo-phalangeal joint, may be normal. The diagnosis is confirmed by X-ray.

Treatment. Where the angulation is mild the deformity should be left undisturbed. Usually the fracture line is stable and requires no protection. No treatment is necessary other than a crepe bandage compressing the hand to reduce swelling. The patient should be encouraged to use the fingers as much as possible. In two or three weeks, when the œdema is reduced and the pain is gone, it will be found that a small hump remains at the level of the fracture line and that the normal dorsal prominence of the metacarpal head is absent. Movement of the

metacarpo-phalangeal joint is normal and function of the finger is perfect. In this instance one can be satisfied with the result.

If, however, it is thought on consideration, that the angulation is too great to be allowed to remain, some effort should be made to reduce the deformity. The patient, naturally, is given an anæsthetic and the metacarpal head is manually pushed backwards out of the palm, counter-pressure being exerted on the fracture line. The simplest way to maintain



FIG 79 (*a*). This is often an impacted fracture and if the deformity is moderate it should be accepted and not tampered with.



FIG 79 (*b*). This is a stave fracture, it is unstable and requires reduction. Only internal fixation is effective

this improved, though not necessarily anatomically perfect, position is to apply a pad of adhesive felt the diameter of a penny in the palm of the hand, over the metacarpal head. A similar piece of felt is placed over the fracture line on the dorsum of the hand. Crepe bandage pressure is applied and these two points of pressure will hold the improved position. Union will take place in about three weeks, when the bandage can be removed and thereafter full function is rapidly restored. This treatment is applied to fractures of the metacarpal necks of the four fingers in equal degree.

Rarely the fracture of the metacarpal neck is oblique in direction caused by a shearing force (Fig. 79b). The fracture is unstable and if it is of the fifth finger it must be reduced and stabilized. If reduction by manipulation is convincing, it should be held by passing a Kirschner wire subcutaneously through the distal fragment into the fourth metacarpal. Two such wires may be necessary to maintain a firm reduction. They are removed in three weeks and movement is soon restored.



(*a*)



(*b*)

Fig 80 (*a*) The surgeon has every reason to be satisfied with the reduction (*b*) The patient can tolerate the splint, but is there a tortional deformity?

Transverse Fracture of the Proximal Phalanges

Although any type of displacement may take place as the result of violent injury, the typical deformity of a transverse fracture of this bone is forward angulation. This inevitably means that the digital theca is invaded and frequently the profundus tendon is damaged by the sharp fragments of bone. This accounts for the frequency with which flexion movement of the finger is obstructed after such an injury. As often as not

this fracture is the result of direct violence and so there may be skin damage or laceration on the back of the finger.

Diagnosis. In nearly every instance the diagnosis is obvious on clinical inspection but it must be realized that there will be a greater degree of angulation shown by X-ray than is likely to be anticipated on clinical observation. Naturally, the finger will be largely useless.

Treatment. Although small degrees of angulation may be permitted to remain, particularly if the fracture is stable, reduction will most likely be desirable. This is achieved under anæsthesia by bending the deformed phalanx forward manually. Occasionally a wire splint is still used to maintain the reduction accurately adjusted to the necessary degree of flexion (Fig. 80). Fixation of the finger in a circular plaster of Paris splint

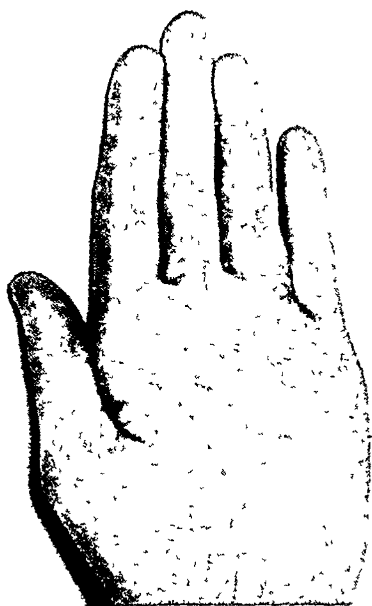


Fig. 81 (*a*). This seems to be a perfectly good hand following a fracture of the proximal phalanx



Fig 81 (*b*). Clenching the fingers shows a very different result

is not to be desired as it tends to congeal the joints and limit subsequent function. It should be remembered that a single bent finger, whichever it may be, always points to the tuberosity of the scaphoid. Therefore, on bandaging or fixing the affected finger in the flexed position it must be aimed in the correct direction, otherwise deformity will be revealed as movement is restored (Fig. 81).

The best routine method of treatment is to place a 2-inch cotton bandage in the palm of the hand, bend the finger over it seeing that it is aimed correctly. The finger is held down over the roll in the palm by means of zinc oxide strapping covered by bandage. Occasionally the pulp of the tip of the finger is sutured to the skin of the palm in the region of the scaphoid tuberosity, in order to make doubly certain that there is no rotatory deformity (Fig. 82). This may be necessary in a patient who

is accustomed to use his fingers for fine work and who must at all costs avoid one finger fouling another in the course of complicated movements. Immobilization should be maintained for about three weeks. When the finger is liberated it is best mobilized by being held to a neighbouring finger by an elastic garter encircling both. The free movement of the normal finger will mobilize the stiff one and full range and control will soon be restored. The method, however, is obviously uncomfortable and disagreeable to the patient and should be avoided unless the highest standard of reduction is necessary.

In the case of multiple phalangeal fractures the surgeon must become obsessed with the idea of early movement (Fig. 83). If the fractures are



Fig. 82 This rather ferocious method of preventing mal-union of phalanges is mathematically effective and foolproof.

at all stable they should be ignored and active movement encouraged at once. If unstable, the fingers should be flexed in the boxing glove manner. At the end of ten days or two weeks movement is coaxed and will be found difficult to restore.

Fractures at the Base of Proximal Phalanges

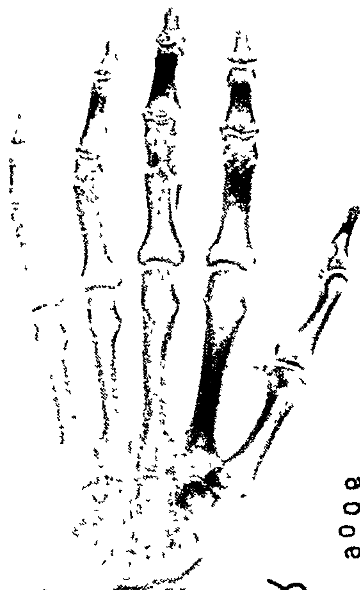
This group is really a sub-division of the previous section. The fracture is caused by indirect violence, usually a dorsiflexion force at the metacarpo-phalangeal joint. The angulation is convex anteriorly. The fracture is usually stable. Sometimes the deformity is so mild in degree that the fracture is missed at first; all the more so because movement at the metacarpo-phalangeal joint is frequently adequate or even full.

Diagnosis. A clinical diagnosis can only be made if deformity is recognizable. Frequently, in spite of quite significant angulation,

palpation is of no help except to detect local tenderness just distal to the joint. Suspicion may be aroused and so an X-ray is taken and the fracture demonstrated (Fig. 84).



(*a*)



(*b*)



(*c*)

FIG 83 (*a*) This hand was potentially stiff from the instant it was burst by the press.

FIG. 83 (*b*) The phalangeal fractures are trivial in this context.

FIG 83 (*c*) To maintain movement is essential This is done by suture of the wounds, ignoring the fractures and moving the fingers, with this result.

Treatment. If the angulation is not more than 25 degrees and the fracture stable, no reduction should be attempted. If, however, the angulation is more severe it is likely that the digital sheath will be damaged disturbing the profundus tendon function. In this case it will be better

to reduce the deformity by a manipulation similar to the previous fracture. The reduction is held in a similar way with the finger flexed over a pad in the palm. Movement should be commenced in about two weeks, as in this instance the finger is apt to get a little stiff because the injury is situated close to the knuckle joint.

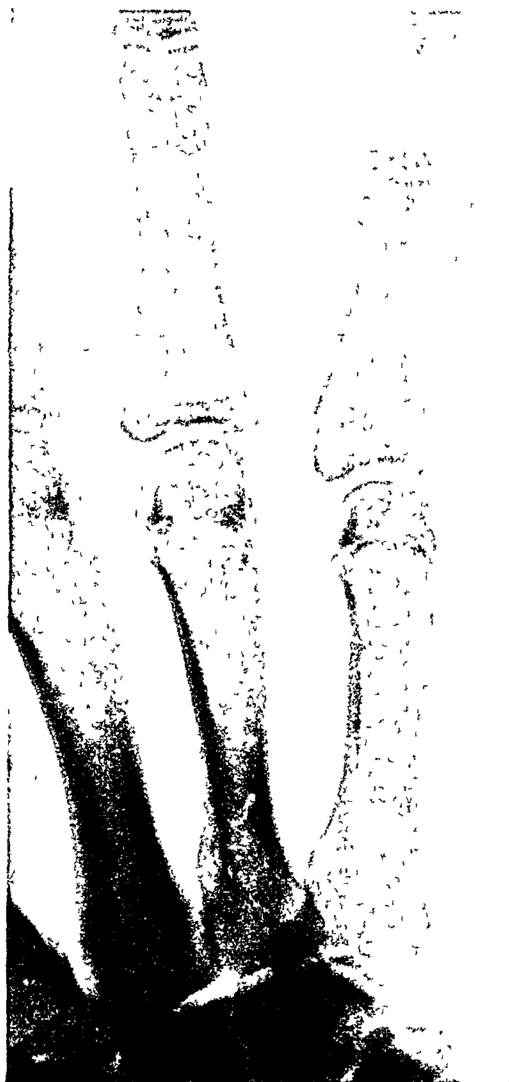


FIG 84. This transverse fracture is often stable, requiring no fixation.

Fractures involving Interphalangeal Joints

(a) *Closed and Oblique*

These fractures, which may occur in both the proximal and distal interphalangeal joints, are unpleasant because the ultimate results are bad. In either instance it is the joint distal to the fracture which is involved. This shearing or stave fracture represents the result of a longitudinal force. The oblique fracture line extends into the interphalangeal joint.

Diagnosis. Frequently the true nature of the injury is missed in the

first instance as the deformity of the finger is not great and the swelling, expected after injury, obscures the nature of the lesion. The finger is rather stiff and the phalanx uniformly swollen and tender on pressure. Clinical examination identifies which phalanx is damaged but the actual details of the injury are only revealed by an X-ray, which should be taken as soon as possible (Fig. 85).

Treatment. Before deciding the details of treatment, the condition of the joint must first be assessed. The surgeon should consider whether the joint has been injured beyond hope of reasonable recovery or whether it is only mildly disturbed. One patient will require flexibility in the



FIG 85. This degree of displacement normally needs surgical reduction Frequently, however, the fracture is represented by a hair-line crack

fingers, whereas another will need strength. If it is decided to accept the deformity, the fracture will not require reduction or fixation. As the fracture is oblique, further displacement will not occur. In such an instance a simple method of treatment is by coupling the injured finger to its normal neighbour, by means of one or two elastic garters, so that the free mobility of the normal will mobilize the injured and potentially stiff finger (Fig. 86).

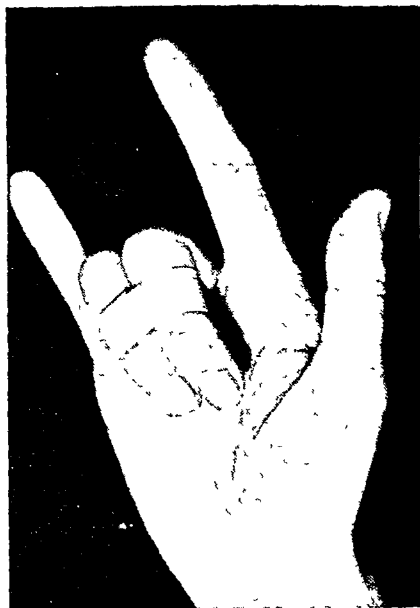
If, however, it is decided that some effort should be made to improve the anatomy of the interphalangeal joint, this cannot effectively be achieved without surgery. The patient is anæsthetized and a tourniquet is applied. A dorso-lateral incision is made over the phalanx and the fracture line is seen after lifting the extensor tendon. Reduction under vision is easy

and usually the joint need not be opened. Reposition is maintained if two short lengths of fine Kirschner wire are inserted transversely, skewering the fragments in accurate reduction. The wires are cut short so that they only just protrude through the skin. The incision is sutured and a bandage is applied to the finger. If possible the finger is coupled to its normal fellow by elastic garters so that mobility is restored as soon as possible. The Kirschner wires are removed under a local nerve block anæsthetic at the end of two weeks, after which time it is impossible for deformity to recur.

The effect of such an injury on an interphalangeal joint is soon irreversible. If more than seven days old, it is best treated by leaving the bone severely alone and making the best of the situation as far as the joint is concerned. Mobility is induced as early and as completely as possible,



(a)



(b)

FIG. 86 These elastic garters are simple to make and are effective in use

by use of garters. These fractures should never be treated by encasement in plaster of Paris. Such a method would ensure unnecessary stiffness of the finger joints. When a professional cricketer sustains this injury, he gets a very serviceable finger if he avoids splintage by a doctor.

(*b*) *Open Fractures*

The probability of stiffness, after a joint has been opened is obvious. If the joint is opened without skin loss by an incised wound, immediate closure is carried out (Fig. 87). If, however, there has been skin loss it is not likely that any useful movement will be preserved because of damage to the extensor tendon. The loss is made good by a free skin graft.

A joint, opened by a laceration that has been sutured, is mobilized by coupling the finger to its neighbour with elastic garters. If more than one



(*a*)



(*b*)



(*c*)



(*d*)

FIG 87.

(*a*) and (*b*) This injury is clearly the result of direct violence Suture of the skin without excision was possible.

(*c*) and (*d*). After using the medius as a lively splint reasonable movement was restored

finger is similarly lacerated and fractured there may be insufficient stability in adjacent fingers so that a stabilizing plaster splint has to be applied for

two weeks, before movement is begun. If a skin graft is necessary to close the wound no effective motion will subsequently be obtained and in this instance a sound ankylosis is achieved by immobilisation of the joint in a functional position for six weeks.

Crush Fractures of the Terminal Phalanges

The terminal phalanx is frequently injured in a crushing episode such as shutting the tip of the finger in a car door, or by having it caught beneath a heavy falling object. This is essentially a soft tissue injury which crushes or bursts the skin and terminal pulp. It is not considered under this section as the bone injury is of minor importance.

DISLOCATIONS

The Carpo-metacarpal Joint of the Thumb

This injury is, in fact, a member of the Bennett's fracture group. The base of the metacarpal is not broken but the metacarpal itself is dislocated from the trapezium.

Diagnosis. This can only be made by X-ray because differential clinical diagnosis from a Bennett's fracture is impossible.

Treatment. When the diagnosis has been made, reduction is easily



FIG 88 (*a*). Dislocation of the carpo-metacarpal joint



FIG 88 (*b*) Maintenance of reduction by Kirschner wire is simple and effective.

accomplished. Unfortunately, however, the reduction is excessively unstable and frequently recurrence of displacement is seen in the post reduction X-ray. Fixation by external splintage is capricious, so that internal fixation is appropriate. The patient is anæsthetized for the reduction and the opportunity can be taken to achieve fixation in anatomical position by use of Kirschner transfixion through the base of the metacarpal into the trapezium and carpus (Fig. 88). The wires are inserted without incision. A compression dressing is applied and remains in place for three weeks, when the wires are removed. The dislocation is stable at this time and encouraged movements will quickly restore normal function.



FIG. 89 (*a*) Dorsal dislocation of the metacarpo-phalangeal joint. Closed reduction was not possible Open reduction succeeded.



FIG. 89 (*b*). Children also are liable to this dislocation

The Metacarpo-phalangeal Joints

i. *The Thumb*

Dislocation of this joint is not infrequent and is a nasty injury. In almost all instances the proximal phalanx is displaced dorsally and the head of the first metacarpal protrudes itself anteriorly and is palpable immediately beneath the skin. The injury is caused by violent dorsiflexion of the outstretched thumb.

Diagnosis. The diagnosis is simple: it is made on a single glance at the deformity (Fig. 89). The patient is usually aware of it himself. The skin is tightly stretched over the head of the metacarpal. The thumb is

quite useless functionally, though some mobility at the carpo-metacarpal joint may be possible.

Treatment. Before the anæsthetic is given the patient should be warned that open operation may be necessary. Frequently, however, closed reduction by the obvious manœuvre is successful. The reduction is sufficiently stable afterwards if it is encased in a compression crepe bandage. The position following reduction must be checked by X-ray. Sometimes, however, on attempting reduction the surgeon has a sense of dissatisfaction and the apparently reduced joint is so abnormally unstable that in all probability the reduction is not complete. At other times it is absolutely impossible to achieve anything approaching reduction, even by the use of quite severe force. In both these instances open reduction should be immediately undertaken.



FIG 90 An open reduction was necessary in this instance

Through the normal anterior incision the flexor pollicis longus tendon is defined on the ulnar side of the protuberant metacarpal head. It will be seen that the metacarpal head has been forced through a tear in the insertion of the thenar muscles. The muscles grip the metacarpal neck, making reduction through the buttonhole very difficult. Some further division of tissue at the insertion of the short muscles of the thumb is necessary to enlarge the hole and then reduction is easily achieved. Two or three stitches of catgut repair the deficiency in the anterior joint capsule and the skin wound is sutured. The joint is stable in slight flexion because the dorsal part of the capsule is intact. A dorsal plaster splint is applied, which remains in position for two weeks. When it is removed movements are encouraged and enjoined until serviceable function is achieved. Frequently full movement is not achieved but this matters little.

ii. *Other Metacarpo-phalangeal Joints*

These joints are intrinsically unstable. Stability depends on tendinous insertions and a relatively strong capsule. Reduction may be blocked or stability reduced if these are widely torn by the dislocation. Once again the usual force to cause these dislocations is excessive dorsiflexion but sometimes, as a result of unusual violence, the phalanx is displaced forward or even laterally (Fig. 90).

Diagnosis. Usually the phalanx is dislocated dorsally and the head of

the metacarpal is prominent in the palm. The fifth finger seems especially vulnerable. These dislocations are rarely multiple. The swelling may be extreme and more often than seems reasonable the dislocation is overlooked for some days. As the swelling recedes the bony deformity becomes obvious. The affected finger, of course, is stiff not only at the metacarpo-phalangeal joint but also at the interphalangeal joints because the flexor tendons are disturbed by the protuberance at the metacarpal head.

Treatment. An open reduction may be necessary and the patient is warned of this possibility before being anæsthetized. With his thumb, the surgeon pushes the phalanx forwards and distally. Frequently an immediate and satisfying jolt will denote an accurate and stable reduction. If this is so, all that is necessary is crepe pressure to reduce and control swelling. Soon, say at the end of a week, the bandage can be removed and movements encouraged. It may be a long time before full movement of the metacarpo-phalangeal joint is restored; in fact sometimes it is never restored but the result is always good.

If the joint is defiant and closed reduction is impossible: an open reduction should be carried out at once. The dislocation is stable because the head of the metacarpal has been forced through a buttonhole in the tough anterior capsule which grasps the metacarpal neck. To achieve a reduction the metacarpal head has to be slipped back through the buttonhole and this is not always easy. If this fact is grasped, reduction can be made through a dorsal incision opening the metacarpo-phalangeal joint from behind. The incision is longitudinal; it is made over the dislocated base of the phalanx. The extensor aponeurosis is split longitudinally and retracted to expose the capsule of the joint. This, too, is incised in a longitudinal direction and a flat, strong elevator is passed into the joint. It is used as a shoehorn to slip the phalanx over the metacarpal head thereby reducing the bone through the palmar capsular rent. Reduction, when it is attained, is obvious. It is immediately stable and nothing further remains to be done but to suture the incision in the extensor aponeurosis with fine wire. When the skin has been sutured the joint is immobilized with the finger about 30 degrees flexed. Fixation is by a dorsal plaster slab. It is removed after ten days, when movement in all directions is encouraged. The patient must be warned, however, that full motion is frequently difficult to restore.

Terminal Joints

Dislocations of the terminal joints are not very frequent. They are caused by a dorsiflexion injury. The thumb is most commonly affected. The patient falls on the outstretched hand and catches the tip of the thumb or finger, so that it is forced into dorsiflexion and dislocated. The digit is held rigidly immobile; function is impossible.

Diagnosis. This is obvious on inspection. It is, however, wise to take an X-ray to see if a small flake fracture involving the joint has occurred. If such is present, reduction may be unstable.

Treatment. If the injury is seen within an hour or two of its occurrence, the correct treatment is to sit oneself beside the patient and, under the guise of a scrutinizing examination, together with a good deal of disarming talk and questioning, suddenly and swiftly to reduce the dislocation by thrusting the terminal phalanx in the obvious direction. The bone must be pushed forward, not angulated. There will be a sudden exclamation, followed by a feeling of relief. In almost every instance the reduction is stable and no splint or bandage is necessary. The joint, however, will not be as freely mobile immediately afterwards as might be supposed and sometimes motion never is completely restored.

Reduction may be so unstable that displacement instantly recurs. An X-ray will reveal that a small chip fragment has been broken off one or other component of the joint. Reduction in this case can only be maintained by immobilization, possibly by a plaster splint, for three weeks. Immobilization will stiffen the joint. Afterwards the finger, though swollen at the joint, will appear relatively normal but movement will be slight. This may represent a satisfactory result for some persons but in those patients who need the full, though perhaps crude, use of their fingers, such a result is not satisfactory. For example, cricketers frequently sustain the same injury in the course of fielding a swift ball in the slips or at the wicket. The livelihood of these men depends on their ability to grasp, and on painless freedom of movement of their fingers. In nearly all instances they are wise enough to keep away from doctors and as a result they furnish themselves with knobbly, deformed terminal joints which are mobile and controlled and painless. If, therefore, it is decided that the appearance is not entirely important, but that serviceable function of the finger is all-important, it is better not to attempt to reduce an unstable joint of this nature. In all instances where this injury is first seen when seven days or more old, it should be left severely alone, no attempt at reduction being made.

The proximal interphalangeal joint is occasionally dislocated. The dislocation is equally frequent in either direction. Reduction is usually easy but may be difficult. The joint is unstable and should be supported by a bandage for a week. Thereafter it is to be mobilized by hitching it to an adjacent finger by a garter.

The Dislocated Semilunar

This condition is apt to be overlooked in spite of clinical examination and scrutiny of the X-ray (Fig. 91).

Ætiology. The method of dislocation of the semilunar is not fully understood. Proximally the semilunar articulates with the radius and the triangular fibrocartilage covering the head of the ulna. The latter is not concave in aspect. It seems possible that the semilunar could be expelled forward, like a cherry stone from the fingers, when the wrist is dorsiflexed in radial deviation. In this position the semilunar would not be supported by the concavity of the radius. This, in fact, may be the mechanism of

many of the displacements but some authorities feel that forward dislocation of the semilunar is related to intercarpal dislocation. It is believed that the semilunar may be displaced forward during spontaneous reduction of an intercarpal dislocation. That is to say, during the intercarpal dislocation the head of the os magnum is displaced behind the posterior horn of the semilunar. As the head of the os magnum reduces itself spontaneously when the dislocating force ceases, the semilunar is knocked forwards out of the concavity of the radius. From an X-ray all that is noted is that the semilunar has been displaced forward and rotated forward 90 degrees. There may also be a fractured scaphoid but that is immaterial



FIG 91 The dislocated semilunar is also rotated through a right angle

to the argument. It can be said in perfect truth that the ætiology is not understood.

Diagnosis. As stated previously, this condition may be overlooked in spite of adequate examination by a knowledgeable surgeon. The patient presents himself, giving the history of injury, perhaps an hour previously, in which the wrist was powerfully dorsiflexed. The region is swollen equally on the front and the back. Movement is considerably restricted in all directions. Furthermore, the patient will claim that attempts at finger flexion are excessively painful and that passive extension of the fingers hurts a good deal. Tingling may be felt in the area of distribution of the median nerve. The X-ray will instantly reveal the condition. This is best demonstrated on the lateral view. On being wise after the event, it is clear that the antero-posterior view is slightly abnormal.

Treatment. In the past attempts were made to reduce the semilunar

from its abnormal position in the carpal tunnel by pressure of the thumb over the front of the wrist with the joint in palmar flexion. This cannot be good for the median nerve which lies between the anvil of the semilunar and the hammer of the thumb. The surgeon is no longer afraid of surgery, nor fortunately, is the patient. Under an anæsthetic and an Esmarch bandage with blood pressure cuff the carpal tunnel is opened by means of a standard incision extending proximally up the crease of the thumb, across the front of the wrist in the radial direction, and up the lateral aspect of the forearm for an inch or two. The anterior carpal ligament is divided. The flexor tendons are separated just to the ulnar side of the median nerve. The dislocated semilunar bone is easily felt pushing its way into the carpal tunnel. With the thumb the semilunar is tilted in the appropriate way, so that the posterior horn begins to engage under the head of the os magnum. A dextrous flick of the thumb reduces the bone beyond all doubt. The skin is sutured and a pressure bandage applied. No splintage is necessary.



FIG. 92. The intercarpal dislocation, characteristically seen in the lateral view often evades detection.

If dislocation of the semilunar bone has been accompanied by a fracture of the scaphoid and the proximal fragment has accompanied the semilunar into the carpal tunnel, the situation is more complicated. In such an instance the wrist should be dorsiflexed two weeks after the reduction and maintained in this position for three months. If by this time it is evident that the scaphoid fragment is necrosed, further attempts to secure union by immobilization will probably be useless (see p. 171).

The Intercarpal Dislocation

This, too, results from forced dorsiflexion of the wrist, no doubt accompanied by a strong posterior shearing force. The distal row of carpal bones is displaced backwards, leaving the proximal row, that is to say the scaphoid, semilunar and cuneiform, in normal relationship with the radius. The dislocation is stable.

Diagnosis. The diagnosis can only be made clinically before obliterating swelling has masked the deformity: after this it can only be

guessed at. The wrist region is thick and yet movement at the wrist is partially retained. Finger movement is fairly free, although extremes are limited and painful. There is no upset in the conduction of the median nerve. The diagnosis is made by the X-ray and not infrequently after cursory inspection of a good X-ray the diagnosis is missed. The antero-posterior view may show very little amiss but a considered gaze at the lateral view will instantly reveal that the head of the os magnum is lying posterior to the semilunar bone which itself is tilted forwards. The semilunar bone lies in its correct relationship with the lower end of the radius (Fig. 92).

Treatment. Treatment aims at reduction of the displacement. This is not always easy and although it may sometimes be accomplished by closed manipulation under strong skeletal traction, it is better openly to reduce the displacement under vision, thereby avoiding additional damage. It is better to approach the displacement from the back through a longitudinal incision correctly planned. The incision should lie just to the ulnar side of Lister's tubercle, so that the extensor longus pollicis is not disturbed. The displacement may be approached by separating the tendons of the extensor communis digitorum. When sufficient separation has been made the deformity can be seen. The head of the os magnum has to be prized forward so that it lies in the concavity of the semilunar. At first the displacement is exaggerated to increase the deformity, thereby allowing the operator to see the semilunar which otherwise is hidden by the os magnum. By means of a blunt instrument the semilunar is rotated so that it lies dorsiflexed in its joint with the radius. Then, in that position and with counter-pressure from the front, the head of the os magnum is shoehorned into the cup of the semilunar and reduction is instantly and satisfactorily accomplished. Unless this initial dorsal rotation of the semilunar is undertaken, it is possible, and even probable, that reduction of the dislocation will displace the semilunar forwards into the carpal tunnel. Open reduction of the dislocated semilunar is best achieved from the front and should this complication of reduction occur a further incision in the front has to be made. The reduction, when complete, is stable· only the skin is sutured. A compression crepe bandage is applied and the tourniquet is released. As days pass the patient is encouraged to move the wrist, thereby restoring function in a matter of some weeks. It will, however, be several months before a final state of recovery is reached and it is unlikely that full movement in any direction will ever be achieved, although the wrist will be serviceable and painless.

SPRAINS

Sprain of Proximal Interphalangeal Joints

This is a common injury and is liable to happen as a result of a fall on the outstretched hand or playing games, particularly cricket. It is

an injury which seems to bewilder and puzzle the patient a great deal, although to the doctor the matter is perfectly clear, obvious and trivial. In nearly all instances an X-ray should be taken to be certain that there is no fracture of the end of the proximal phalanx extending into the joint. As a result of this injury the proximal interphalangeal joint becomes painful and swollen. Movement, which is a good deal restricted, increases the pain. The patient complains that he often unwittingly knocks the finger and this is rather unpleasant.



FIG. 93. The result of an interphalangeal hyper-extension sprain fracture



FIG. 94. The subluxation accompanying the fractures augments the need for early movement rather than splintage.

The evolution of the recovery is as follows: the pain nearly always disappears in about six or eight weeks. The swelling is liable to remain for many months and sometimes it never completely disappears. It is possible that after the mildest sprain of an interphalangeal joint a finger will remain permanently fusiform. If a finger is neglected, full movement will not spontaneously be restored. The patient himself must work at the joint in order to obtain good extension and flexion. This is done by connecting the injured finger to its neighbour by two elastic garters

(see Fig. 86). By this means everyday function is used as treatment. It is unnecessary for a physiotherapist to waste time doing this simple manœuvre. These matters have to be explained to and understood by the patient in the early stages, otherwise he will constantly mutter his disappointment at the result, complaining that the finger is swollen and stiff. Treatment, by immobilization on a splint or wrapping the finger in a bandage, is disastrous and will inevitably lead to irreversible stiffness. The patient's grumbles will continue, and with reason.

Sprain Fractures of the Proximal Interphalangeal Joints

Sometimes a hyperextension force that sprains the joint continues until the anterior lip of the middle phalanx is avulsed and slightly displaced. The X-ray is of only academic interest (Fig. 93). The potential stiffness of the sprained joint is of major importance. A force acting laterally on the joint is more likely, if severe enough, to depress a condyle of the proximal phalanx, after the manner of the ' bumper fracture ' of the knee. In both instances movement must be induced as soon as possible and the X-ray appearance is to be ignored. The technique of treatment is the same as for a sprain of the joint. An elastic garter holding one finger to another induces movement and affords support.

Sprain Fractures of Terminal Joints

The terminal joints are often sprained by injury and fairly frequently small pieces of the condyle of the proximal end of the distal phalanx are split off, producing what is technically a fracture into the joint. They are discovered only by X-ray (Fig. 94). They are of significance only in this respect. Splintage, or immobilization of a damaged terminal interphalangeal joint, will assuredly lead to irreversible stiffness. It must not be thought by the surgeon that continued mobility will lead to joint instability or even subluxation. The surgeon should not concern himself with union of the fracture, because it makes no difference whether union of the small fragment takes place or not.

The guiding principle of treatment of these sprain fractures of the terminal joints is early and complete movement. Motion at first must be passive and coaxed. Later on, as tendon action takes over, the movement obtained early whilst the joint was swollen and painful, will be maintained. Those who do not seek the advice of doctors are apt to get better results than those who submit to orthodox surgical treatment.

Joint Instability following Injury

The metacarpo-phalangeal joint of the thumb is peculiar in that a sprain of the joint may be followed by instability. This is an unusual feature, because, ordinarily, a sprained joint is a stiff joint, often permanently. The knee joint is an exception to this, for occasionally a sprain of the external lateral ligament permits instability afterwards. In

the finger joints instability following spraining is unknown, except in the metacarpo-phalangeal joint of the thumb.

When the immediate swelling diminishes and the pain reduces itself, the patient will notice that the grip of pinching between the thumb and the index finger is impaired because of lateral instability of the metacarpo-phalangeal joint. This permits the thumb to be pushed aside by the pressure of the index finger. The instability can be readily demonstrated (Fig. 95).

It is often a ski-ing injury and the early stages of a sprain of this joint should be taken seriously and immobilization, either by a light plaster splint in the slightly flexed position or by application of zinc oxide strap-

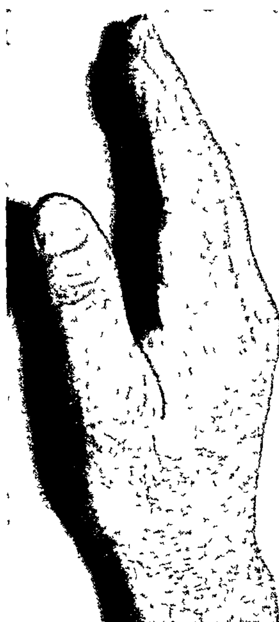


FIG 95 (*a*) The thumb is normal in attitude and contour.



FIG. 95 (*b*). A subluxation is easily produced; an unusual sequel to spraining except in this joint.

ping, should be enforced. Fixation of this nature for two or three weeks is liable to produce stiffness of the joint in the hinge direction, but in the normal course of events only a slight amount of flexion of this joint is necessary. The varying ability of patients actively to bend this joint is very obvious if several are examined. At the expense of a slightly stiffened joint in the hinge direction, a greater degree of lateral stability will be obtained after such an injury. This is of importance because the thumb regains a normal degree of strength. If the lateral stability is impaired, the thumb is considerably weakened.

The treatment of established instability is unrewarding and the patient should be discouraged from surgery. Attempts at cobbling up the lengthened lateral ligament are made, if this stiffens the joint the result may be good

CHAPTER 9

POST-TRAUMATIC DISABILITIES

The Swollen and the Stiff Finger

Local swelling of the hand or finger is an almost invariable sequel of injury. The swelling may not be confined to the site of the injury but may extend distally to include all the fingers. The swelling is due, initially, to hæmorrhage at the site of injury; this is liable to set up back pressure in the distal parts because of partial obliteration of the veins and lymphatics. The distal swelling may be further increased by application of a dressing or bandage. Joints in the swollen locality will certainly be limited in movement to some extent, often very greatly. The finger may be partially blue in colour, representing mild venous obstruction.

Peripheral œdema, due to proximal obstruction, can be reduced in several ways. The simplest method is by constant pressure locally applied. Secondly, the swelling may be drained away by posture, that is to say if the part is elevated the tissue fluid will track proximally and return into the general circulation. Finally, œdema can be induced to disperse by active use and mobility of the swollen part. It is an almost universal practice after an injury or operation to keep the hand elevated in a sling if the patient is ambulant, or by some suspensory device if the patient is in bed. Application of the principle of postural drainage is a useful adjunct but it is not in itself sufficient wholly to control post-traumatic swelling. Greater reliance is placed upon the use of a bandage, whereby the part is compressed to a reasonable extent so that capillary stasis is prevented. Frequently after injury it is not possible usefully to apply the principle of movement in order to decrease œdema because the injury itself has prevented movement.

As a general rule surgeons are apt to rely on pressure as a means of discouraging swelling following injury. As the swelling decreases, movement in the neighbouring joints increases. The limitation of movement, which normally accompanies swelling of the digit, does not imply special involvement of the joint; it is not fusiform, as it would be were there articular pathology. The finger is stiff because the tissues are swollen and inelastic. The most practical way of applying pressure to a swollen digit is by the use of Tube Gauze. This is a loosely woven tube of cotton stockinette which can be applied, by a simple instrument, under tension and torsion. The result of this is a circumferential compression. The degree can be varied by the tightness of the twist and the number of layers, usually three or four, that are used. The tip of the finger is not covered so that the circulation can be watched. The tube gauze is renewed as necessary and in a few days swelling of this nature can be

eliminated so that the capacity for movement is restored. The more completely the œdema is removed, the less likely it is to recur from stasis. When swelling is reduced, passive coaxing of movement will be rewarding. Heat at this stage is not wise, as it may induce more swelling.

The Stiff and Shrivelled Finger

This description is applicable to a finger which was swollen previously but in which the swelling, either spontaneously or as a result of treatment, is reduced, leaving the local joints stiff to a variable degree. There is usually a flexion deformity of the joints. The sequence of events is that the swollen finger is not fully mobilized whilst swelling is decreasing, so that the œdema is permitted to congeal, thereby laying down fibrous tissue which effectively restricts motion of all tissues in the region. Not only is the joint stiff but in other parts of the finger it will be noted that the subcutaneous tissue is wasted and restricted in its motion. The interphalangeal joints may be swollen slightly in comparison with the surrounding atrophied tissue but they are not tender on local pressure. At whatever point movement is restricted the block will be complete and absolute and not springy. Sometimes it is difficult to decide whether the stiffness of the finger is due to intrinsic limitation of the movement within the joint or to tendon adherence. Relaxation of the tendon by posturing a proximal joint will usually supply the answer and this impression is augmented if there is absence of tenderness on lateral pressure of the affected interphalangeal joint.

Treatment. Clearly there is an intermediate stage between the swollen and the atrophied finger. This period may last for several weeks and physiotherapy at this stage may increase movement. It is during this transitional phase of stiffness of the joint that wax treatment has its most useful application. The hand is plunged into paraffin wax, heated to a temperature of 115° Fahrenheit, which has the effect of heating the tissue beyond the degree normally possible by water without blistering. While still hot from the wax the fingers are passively manipulated. The degree of force permitted is not possible to define. If the efforts are too forcible the joint will become irritable; if coaxing efforts are too modest they will be useless. Experience will show the maximum force that can usefully be applied. Hot wax and manipulations may be continued for a long time.

A finger which is shrivelled and stiff presents a problem. It will be evident that the capsule of the joint is so rigidly shortened as to defy increase in movement merely by coaxing. This may lead the surgeon to consider the possibility of manipulation of the joint under an anæsthetic. Forcible manipulation of finger joints is not rewarding. There may be a small initial increase in range but it does not last and is apt to be replaced by greater stiffness. Stiff metacarpo-phalangeal joints are indeed a great handicap. The proximal interphalangeal joints are less important and in this context stiff terminal joints do not matter very much.

The Metacarpo-Phalangeal Joints

Stiffness of the metacarpo-phalangeal joint is an unpleasant and limiting handicap, especially if the joint is held in the extended or nearly extended position. It is noticed clinically that attempts passively to flex the joints produce a depression on the dorsum (Fig. 96a). The base of the phalanx is stuck and does not ride round the knob of the metacarpal head. Attempted flexion produces the depression because the result of force is to produce a hingelike effect. This stiffness is, in fact, due to adherence of the volar capsule to the articular cartilage of the head of the metacarpal which prevents the phalanx from sliding. The lateral capsule is also contracted and tight but the depression, on attempted movement, denotes that no improvement can be obtained unless the capsule is lifted from the volar aspect of the metacarpal head.

Treatment. Nearly always the stiffness involves the four metacarpo-phalangeal joints; not always to the same degree however. The collateral ligaments of the metacarpo-phalangeal joints have to be exposed. Under

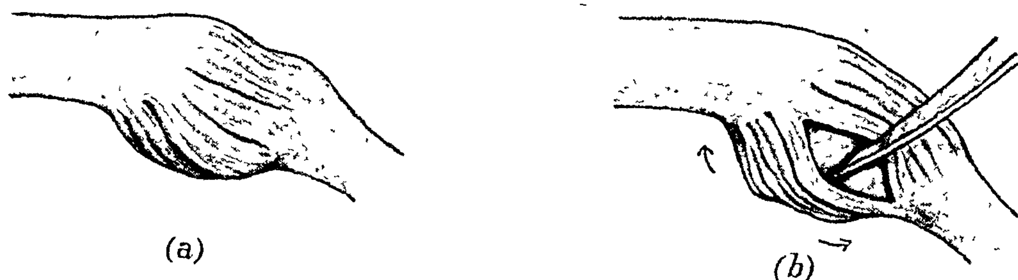


FIG. 96 (*a*) When the capsule is adherent attempted flexion produces a dimple on the dorsum. (*b*) The instrument is to be swept proximally, separating the capsule from the head of the bone.

a tourniquet this is done by a dorsal incision an inch or more long, made in the cleft on either side of the affected knuckle joint. The middle three incisions are used to approach the sides of adjacent joints. The ulnar aspect of the little finger and the radial aspect of the index are approached through separate incisions. The extensor expansion of the joint is exposed and split obliquely in the direction of its fibres. The split tendon is retracted sufficiently to expose the collateral ligaments. An ellipse of capsular tissue, lying obliquely in the direction of the fibres, is removed from the lateral aspect of the joint. A strong, blunt pointed, curved probe is passed into the joint on the volar aspect. It is then swept proximally over the rounded metacarpal head to separate the adherent capsule (Fig. 96b). This manœuvre is repeated on each stiff joint and must be complete. A portion of capsule must be excised from both sides, otherwise the gain in movement is slight and a rotation deformity is apt to develop. When all the affected joints have been treated in this manner, the skin incisions, five in number for the full set, are sutured.

After a compression bandage has been applied, a dorsal plaster splint

is made to hold the metacarpo-phalangeal joints flexed at a right angle. The terminal joints of the fingers are not restrained. In ten days this plaster fixation is removed as well as the stitches. Efforts are made to restore control of the joints and regain extension. After-treatment consists principally in restoring extension and maintaining flexion. Lateral deviation of the proximal phalanges, together with axial rotation, must also passively be coaxed from the joints. Such treatment cannot be hurried and it is likely that it will be several months before the full advantage of the operation has been gained.

The Proximal Interphalangeal Joints

Stiffness of these joints, especially in the straight position, renders the fingers almost useless. If the fingers are bent to half a right angle the hand has, at least, some grasping ability if the metacarpo-phalangeal joints are mobile.

Attempts to mobilize stiff joints are of doubtful value. If the X-ray shows a remaining joint space, it is possible that the stiffness is capsular in origin. Division of the lateral capsule through two appropriate incisions may permit some free movement but it is more than likely that the flexor tendons will also be adherent and so unable to make use of the freedom gained. If there is reason to believe that the tendons are capable of control, an attempt at increasing movement by a division of the lateral capsule may be made.

If, however, the interphalangeal joints are in a state of fibrous ankylosis which is unsatisfactory, the correct treatment is arthrodesis. The position for arthrodesis is predetermined and the joint is opened dorsally. The remains of the articulation are destroyed and the position is held by crossing transosseous wires. These are removed in six weeks or two months, when the union is sound.

The replacement of one component of a stiffened joint by a foreign body is a technique of mutilation which is beginning to threaten patients. By analogy it is safe to condemn the method in advance. Foreign components of inert material have a limited use for a limited time. To expect free movement for an unlimited time from a false joint is silly and contrary to the known facts.

Shortened Intrinsic Muscles

This clinical syndrome occurs more frequently than is supposed. Since it is usually transitory the disablement is short lived. By definition it is a state in which the interosseous muscles and thumb adductors are shortened and require stretching. Clinically it is found that flexion of the interphalangeal joints is limited to a greater extent when the metacarpo-phalangeal joints are straight than when they are flexed. For obvious reasons, therefore, this particular disability may pass unnoticed if the limitation of movement of the fingers is considered to be due to a general

post-traumatic stiffness of the hand. The condition will only be noticed if an effort is made to find out if it is present.

The lack of extensibility of the intrinsic muscles of the fingers may result from any condition in which the palm of the hand is temporarily engorged by hæmorrhage or œdema. It is probably true that limitation of interphalangeal flexion when the metacarpo-phalangeal joints are straight is a normal accompaniment of a swollen and congested hand, whatever the cause. In short-term congestion the contracture is transitory. If, however, œdema of the hand persists, shortening of the intrinsic muscles may last a good deal longer. The most frequent example of



Fig. 97. If this splint extends too far distally on the index the knuckle becomes stiff; if not far enough the splint is ineffective.

this phenomenon is to be found on examination of the hand two or three days after a Colles' fracture. A particular example of shortened intrinsic muscles often follows a crushing of the base of the thumb. If the thumb adductors become infiltrated with hæmorrhage, they are liable to become progressively contracted in a disconcerting way. The result is that the thumb becomes adducted, due to progressive fibrosis closing the first intermetacarpal cleft.

Treatment. The condition can be forestalled by the physiotherapist, potentially contracted muscles are stretched as soon as possible after the injury. Coaxed flexion of the interphalangeal joints, with the knuckle joints extended, should be part of the normal physical treatment of an injured hand. This also applies to the patient with a Colles' fracture,

while the wrist is immobilized in palmar flexion in plaster with the fingers free. If stretching is carried out properly the potential deformity is almost always prevented. If the tendency is persistent, or if the deformity is established when first seen, improvement can be gained by forcibly stretching the shortened muscles under an anæsthetic. The manipulation is simple: the manœuvres are obvious. Active physiotherapy is begun the next day and improvement follows.

The adducted thumb is not easy to correct once it has developed. Intermittent stretching is not effective; a constant abducting force is necessary. This is best achieved by applying a saddle-shaped plaster



Fig 98 (*a*) Apart from the position of the fingers the wasting of the first dorsal interosseus muscle is to be noted.

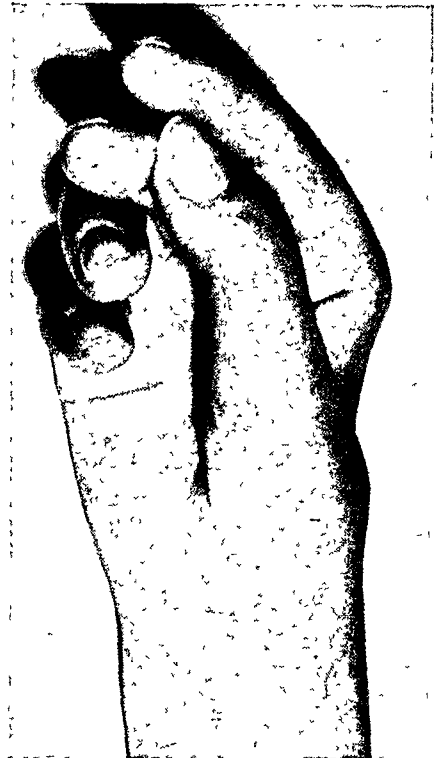


Fig. 98 (*b*). The main d'accoucheur.

splint to the first cleft in the position of maximum abduction. The splint is renewed from time to time, in gradually increasing abduction (Fig. 97).

Volkmann's Contracture of the Intrinsic Muscles

This condition is related to that described in a previous section but is much more severe and the change in the muscle is irreversible.

Diagnosis. The condition can never be mistaken, provided the hand is sufficiently examined. There will be a history of injury or mutilation in the past, together with present disability of function. The appearance of the hand is characteristic. The fingers are held extended at the inter-phalangeal joints and slightly flexed at the metacarpo-phalangeal joints.

The fingers are glossy and atrophic and held close together, usually with the index and fifth fingers lying anterior to the middle and ring fingers. The dorsum of the hand at the level of the knuckle joints is convex in shape; the palm is concave. The thumb is held adducted across the palm lying on the index, flexed at the metacarpo-phalangeal joint and extended at the tip joint. It is, in fact, the *main d'accoucheur*. It will be found that the fingers and hand are stiff; that is to say the deformity is fixed (Fig. 98).

Ætiology. Volkmann's ischæmic contracture is caused by death of muscle fibres and their replacement by inelastic fibrous tissue. The extent of the replacement is variable and so, therefore, is the fixity of the deformity. Volkmann's contracture only develops in a confined space such as the palm of the hand, the forearm, the calf and the foot. Nearly always the exciting cause is hæmorrhage which, by extravasation, separates muscle fibres one from another, depriving the central ones of their blood supply. These muscle fibres inevitably die and are replaced by fibrous tissue. The proportion of surviving fibres will depend on the amount of hæmorrhage and of the force behind the extravasation. The hand itself need not be injured. If bleeding occurs in the forearm in which the deep fascia is intact, or if the forearm is encased in a plaster splint or a tight bandage, the hæmorrhage may be forced through the carpal tunnel into the depths of the palm, thus gaining access to the intrinsic palmar muscles, killing some of the fibres. Stiffness caused by extensive injury to the hand may mask the typical appearance of a Volkmann's contracture, but contracture is not very likely to follow an open injury of the palm. It is excessively rare for Volkmann's contracture to follow compound fractures of metacarpals because the extravasated blood can escape dorsally into the dressings, rather than force its way between muscle bundles. The dangerous injury is the closed crush of the palm not relieved by incision. The condition, however, is equally common following a severe injury to the forearm, requiring plaster fixation.

Hæmorrhage is not the only cause of ischæmic contracture of the hand. A patient lying on a hard operating table, with the hand tucked in repose under the buttock, may suffer this disability following a long abdominal operation. Presumably the hand is ischæmic due to pressure and muscle fibres die. Sometimes this condition follows an injury to the wrist, in which both ulnar and radial arteries are divided. A keen surgeon may take a long time to effect a primary repair of the tissues which are damaged, using a tourniquet. This effectively obliterates any collateral circulation which may normally be present. The blood supply to the hand is so diminished that ischæmia of the muscles of the thenar and hypothenar eminences accompanies that of the deep palmar muscles. In palmar ischæmia due to hæmorrhage, only the palmar interossei, the lumbricals and thumb adductors are affected. In this last instance the affection is more widespread.

Treatment. For the fully-developed instance of Volkmann's ischæmic contracture of the hand, physiotherapy has nothing to offer. Contracted

intrinsic muscles hamper normal use of the fingers; the obstetrical hand is of use only in obstetrics. Improvement in function can only be achieved by division of the tendons of the interosseous muscles. On occasions it is possible, under an anæsthetic, to rupture these tendons. More often, however, they have to be divided with the knife.

Closed Correction of the Deformity. The patient is anæsthetized and the fingers are fully flexed into the palm by the surgeon's hand. With the interphalangeal joints still fully flexed, the metacarpo-phalangeal joints are firmly and strongly hyperextended. Sometimes great force is needed and during the manœuvre the tendons may be felt to rupture. If no rupture occurs, it may be possible to effect this by forcibly abducting the finger with the metacarpo-phalangeal joints held fully extended and the interphalangeal joints flexed. If neither of these manœuvres succeed, the surgeon can only have recourse to open division. It will be obvious that the interosseous tendons of insertion have been ruptured by the fact that the finger can easily be flexed at the interphalangeal joints without force while the knuckle joint is held extended.

Open Correction. The approach to the tendons is made through an incision similar to that used for a capsulectomy to correct fixed extension of the joints. In a bloodless field incisions are made in the clefts between the fingers at the level of the metacarpo-phalangeal joints and on the radial aspect of the index and the ulnar aspect of the minimus. The incisions are prolonged a little more distally than for capsulectomy and the interosseous tendon is found approaching from below. When it has been identified and divided, the finger is instantly liberated. Both sides of each finger require to be released. Since a Volkmann's contracture affects the palmar interosseous muscles more severely than the dorsal, sufficient liberation of the finger usually follows division of insertion of the palmar muscles, that is to say the muscles inserted into the extensor aponeurosis. If, however, lateral movement at the joint is not fully restored following division of interosseous insertion into the extensor cap, the insertion of the dorsal interosseous into the proximal phalanx should be sought and also divided.

Adduction of the thumb is corrected by dividing the adductor insertions into the base of the proximal phalanx. This is done through a dorsal incision in the first web, parallel to the first metacarpal. The adductor muscles are easily identified and they are divided close to the bone. If the thenar muscles also are ischæmic, the metacarpal bone has to be filleted extensively before it can be abducted away from the palm.

After-treatment varies with the extent of the surgery. The application of a firm compression crepe bandage in a neutral position is all that is necessary after a simple tenotomy of the interosseii and thumb adductors. Movement should be started at once and the compression bandage can be released in ten days.

If the thumb has also been filleted and a capsulectomy performed, the knuckle joints must be held flexed at a right angle by a plaster slab and

the thumb held in abduction by a plaster saddle splint (Fig. 97). This position is retained for ten days and then the knuckle joints are liberated and moved as much as possible. The thumb must be held abducted for three weeks before being released, otherwise the deformity will relapse.

Deformity of long standing is resistant, and division of muscle insertion must be combined with capsulectomy. The necessity for a capsulectomy is evident if, after tendon division, the fingers cannot be flexed fully at the knuckle joints. If the deformity has been present for several months it is wise also to divide the transverse metacarpal ligament. This can be done through the same incision by passing the knife through the cleft between the metacarpal heads, towards the skin of the palm. The ligament is felt with the knife. Its division is obvious and satisfying and will permit flattening of the palm, which may not be obtained simply by division of the interosseous insertions.

Disability will remain, even after surgery to correct intrinsic contracture of the hand is considered to be successful. The hand is infinitely more useful than before operation but its function is comparable with the clumsiness noticeable with a low ulnar nerve lesion. Fine movements are not possible and there is disablement, even with dressing or shaving. Before correction, however, the hand is little better than a paper-weight and so awkward that it is impossible to cover with a glove.

Sudeck's Atrophy

During the course of his original description in 1900, Sudeck mentioned the positive X-ray change that is part of the syndrome. Since that time various authors, including Middleton and Bruce, have emphasized the X-ray appearance of bone decalcification or atrophy. With the popularity of the theories of Leriche, it was assumed that Sudeck's atrophy, or painful post-traumatic osteodystrophy was, in fact, an osteoporesis due to hyperæmia caused by a local autonomic axon reflex. Progress, regarding ætiology and treatment, was bogged down in this meaningless theory. Now it is realized that the condition is closely allied to causalgia, that is to say it is neurogenic in origin, that it is essentially ischæmic in character and that it can be relieved by destroying the autonomic vasoconstrictors.

Diagnosis. The single feature in the ætiology, beyond dispute, is injury; which may be mild or severe. It seems more frequently to follow a mild injury than a severe one but this observation may not be correct. The connection with injury is absolute: it is in fact a post-traumatic state. In spite of awareness on the part of the clinician, it is not recognized until four or five weeks, or even longer, from the injury. In fact Sudeck's atrophy separates itself insidiously from usual and expected post-traumatic stiffness. The clinical appearance, when fully developed, is unmistakable: the fingers are swollen and taper to the tip and the normal wrinkles of the knuckles are missing. The colour is a combination of pink and blue. All the metacarpo-phalangeal and interphalangeal joints are stiff. The joints are tender on pressure and painful if movement is forced. There is

spontaneous pain. In addition, the back of the hand is cold, hairy and moist with foul sweat and the nails are uncut. Sometimes, if the injury is localized, only a single digit is affected. The X-ray is always charac-



FIG. 99. The X-ray appearance of Sudeck's atrophy is different from that occurring in infective or polyarthritis

teristic from a month or so after the injury. There is a good deal of punctate and general bone atrophy, with pencilling of the cortex (Fig. 99). This condition seems prone to occur in a patient who is also difficult

and unco-operative; it is unlikely to occur in the cheerful extrovert who normally minimizes disability. Sudeck's atrophy may be unavoidable. This is not known for certain; but the clinician has a feeling that it can be avoided if movement, either passive or active, is induced into the injured part within a few days or weeks of the injury. Some surgeons and rehabilitationists deny the existence of Sudeck's atrophy as a separate entity. They may be right. Perhaps it bears a similar relation and importance to normal post-traumatic stiffness as does the finishing straight to the rest of the course.

Treatment. This is long and arduous. The aim of treatment is to restore motion and this is done by moving the finger joints by passive coaxing and mild force. The force may be gradual but it must always be mild. Heat, whether radiant, infra-red or moist heat, probably has little effect though it may discourage vascular stasis. Active movement is encouraged as soon as controlled movement is restored. Purposeful reconditioning is indicated.

The injection of intra-arterial procaine has recently been in vogue. Few surgeons have great experience of the method. It is usual to cut down on the brachial artery in the arm and to make a direct injection. During the injection a dramatic flush appears in the hand. The temperature rises rapidly and the whole hand feels warm and looks pink and healthy. This sensation also is subjective. Unfortunately this response of dilatation of the artery to procaine is transitory, but while the hyperæmia and accelerated blood flow is present the patient seems almost miraculously to have more movement in the affected joints. It is unfortunate indeed that a long term hyperæmia cannot be simply induced by one or two injections of this nature. Intra-arterial injection of procaine, though of diagnostic value and clinical interest, is not a therapeutic measure of much use.

Other measures are of more value. A stellate ganglion block has the effect of accelerating blood flow in the arm. The improvement, noted immediately after a successful stellate block, lasts longer—perhaps for three hours—and thereby seems to be more effective. The technique of a stellate block is as follows: the patient lies supine, with the head turned slightly to the opposite side. The skin of the posterior triangle is prepared for insertion of the needle, posterior to the sternomastoid muscle, at a level with the cricoid cartilage. The needle is passed backwards and inwards at an angle of 45 degrees, inclined neither upwards nor downwards, until it strikes the body of the sixth cervical vertebra. The needle passes behind the vessels. After attempting to aspirate, 5 c.c. of 1% Xylocaine solution is injected. This solution, being diffusable, nearly always ensures a successful ganglion block. A Horner's syndrome accompanies a successful stellate block. Later there is flushing and a subjective feeling of heat in the affected hand. Skin temperature is raised and instead of the cold, blue and sluggish circulation there is heat, pinkness and brisk vascular response to pressure. On an average such a change lasts about

an hour, sometimes much longer. The stellate block is not an unpleasant procedure to experience and it may be repeated four or five times. It seems that repeated stellate blocks have a beneficial effect on the sluggish circulation which is cumulative.

Stellate ganglionectomy produces a dramatic and lasting improvement in Sudeck's atrophy. The limb becomes warm and dry and is instantly less painful. The surgeon should not withhold surgery. A severe case which is improved temporarily by stellate block should be offered ganglionectomy without waste of time. The ealier it is done after the injury the less the chances of irreversible psychic changes developing. The patient awakens with good circulation and almost no pain. With improved circulation it is possible to handle the part so that movement of the stiff joints and the general nutrition of the hand can be improved.

In some instances, however, Sudeck's atrophy is an incurable complication of injury. This does not matter very much if the injury was extensive and has itself so impaired function that the hand is of little use. Often, however, this condition develops after a trivial injury, which itself does not jeopardize function. Local physical treatment by heat, using paraffin wax, movement and encouragement is the essential basis for improvement. The adjuvants to treatment, such as the stellate block or ganglionectomy, cannot be used to replace the long and arduous local physical treatment which is necessary. There must be goodwill on both sides.

Painful Digital Neuromata

This term applies only to a terminal neuroma and not to division of a digital nerve. Neuromata, therefore, only complicate amputations. A painful digital neuroma may follow both traumatic and elective amputations. The clinical picture is easily recognized. The patient, with a certain amount of pride, demonstrates the mutilated hand with one or more digits amputated. Occasionally the stumps look surgically satisfactory; usually, however, it is obvious that they are far from ideal. The stump that seems never to be painful is the one with plenty of mobile terminal skin. This does not endorse redundancy but there should be enough skin to permit sufficient mobility of the soft parts. As the examiner approaches to palpate the hand it is quickly withdrawn with expressions of concern. Usually the patient is so wary that it is impossible to palpate the tender area attributed to the digital neuroma.

The clinical syndrome is a phenomenon difficult to understand. Ordinarily, when a peripheral nerve is stimulated, pain is experienced in the area of normal skin sensibility of the nerve. In the case, however, of the digital neuroma, when the end bulb is stimulated by pressure, complaint is made of local pain. The neuroma syndrome is more likely to be present if there is adherence of the scar to the end of the stump, which adherence probably involves the digital nerve too. But this is by no means constant and on occasions a great complaint of discrete acute tenderness is made when from the surgical aspect the stump is entirely satisfactory and scar

free. Considering the number of fingers amputated for one reason or another, the amount of clinical trouble attributable to digital neuromata is negligible.

Treatment. It must be recognized that the complaint of a painful digital neuroma is often an expression of anxiety on the part of the patient concerning the course and outcome of litigation related to the accident. This must be taken into account when evaluating the severity of the complaint and estimating the probabilities of improvement. The days of local and repeated percussion of the neuroma are finished. This treatment has been superseded in the hands of some enthusiasts by submitting the neuroma to some form of supersonic vibration. In the minds of some this treatment has a reputation for dissolving scar tissue. In such instances the adherent end bulb would presumably be liberated. Treatment of this nature is carried out by practitioners without other methods of treatment at their disposal.

If it is decided that a painful digital neuroma merits treatment, division of the affected digital nerve at a distance from the terminal neuroma is the method of choice. The course of the digital nerve is known. At some convenient surgical spot the nerve is found through a correct and appropriate incision and a centimetre or so of nerve is removed. The skin is sutured and the incident is closed. The patient has no fuss made over him; he is not asked if he is better. The matter is considered in a rather casual light and the patient is discharged from hospital at the earliest possible moment. The stitches are taken out at the appropriate time and the man is put off treatment and not seen again. It is likely that the neurosis of a painful digital neuroma will be broken by division of the affected nerve, at a distance, if thereafter the man is not subject to surgical enquiry and concern.

INDEX

PRINTED IN GREAT BRITAIN BY THE WHITEFRIARS PRESS LTD.
LONDON AND TONBRIDGE